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Climate variability, biodiversity dynamics and perceptions of local populations in Waza National Park (Far North Region, Cameroon)

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Climate variability is one of the major ecological challenges of the 21st century in Waza Logone Plain in the Far North region of Cameroon. The physical environment in this area has almost completly deteriorated as a result of declining rainfall and rising temperatures. A study was carried out to understand the dynamics of biodiversity in terms of climate variability in the Waza National Park. This study was based on both the trends of climatic parameters on biodiversity and perceptions of local populations over the last forty years. The adapted approach combines (i) the modeling of climate data through MINITAB 17 Software, (ii) the analysis of wildlife census data and (iii) the digital analysis of satellite images using ENVI 4.5 and QGIS 2.17 Software. The results showed a negative evolution of climatic parameters during the last forty years. The general negative trend of biodiversity evolution of both fauna and flora is a result of the continuous degradation of the Waza National Park. The results of different wildlife census, the spatial analysis and the perceptions of local people confirmed the trend to the degradation of the park and biodiversity losses. Concrete measures of management of the Park should be taken by stakeholders in order to hinder the biodiversity losses, including the construction of water ponds and cartesian wells as well as the enrichment of the park with woody species.

Key words: Climate variability, land degradation, biodiversity dynamics, biodiversity losses, Waza Logone Plain, Cameroon.

INTRODUCTION

Since the United Nations Conference on Environment and Development (UNCED) held in Rio in June 1992, the issues of climate change and variability have become a priority in the protection of the environment, both in industrialized countries historically responsible for these changes, than developing countries. This awareness of the public opinion of the climate issue and the awakening of scientists to these problems were salutary because a wind of protest already blew on the developed world involving companies deemed too subject to the

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technology and industrialization, which are the main sources of greenhouse gas emissions (Merle, 2002).

According to the IPCC Fourth Assessment Report (2007), the current concentration of carbon dioxide is the highest ever seen in the last 420 000 years, and the growth rate recorded in the last century has been unprecedented since at least 20 000 years. Changes in climate have caused impacts on natural and human systems on all continents and across the oceans in recent decades (IPCC, 2014). The rate of global warming observed (more than half a degree Celsius in a century on the globe) and expected (from 1.1°C at best to 6.4°C at worst, on average overall, between 1990 and 2100) is a hundred times higher than the average speed of variations naturally imparted to the Earth's climate (Gnangle et al., 2012). In addition to the rise in average temperatures, the manifestations of global climate change are, among others, the rise in the level of oceans and seas, and rainfall variability. The impacts of these changes will affect all countries of the world, with varying degrees depending on the region (Tarhule, 2011).

Many terrestrial, freshwater and marine species have shifted their geographic ranges, seasonal activities, migration patterns, abundances, and species interactions in response to ongoing climate change (IPCC, 2014). They pose a significant threat to growth, sustainable development and the achievement of the Millennium Development Goals (MDGs) in Africa (NEPAD, 2007). Africa, in particular, is the continent least responsible for climate change, but it is particularly vulnerable to their effects. Janet (2009) even speaks of an implicit injustice, as the poorest and most vulnerable people, who are the least guilty in the gradual increase of greenhouse gas emissions, are the most affected and the least capable to adapt to the effects of climate change. Additional 75 to 250 million people are expected to suffer from water scarcity aggravated by climate change in sub-Saharan Africa by 2020 according to IPCC report. As climate has a major influence on the global environment, its disruption could have a negative impact on the functioning of both terrestrial and maritime ecosystems. Changes in the frequency, intensity, extent and status of disturbances will affect the risks and the rate of replacement of existing ecosystems by new ecosystems (Ouoba, 2013). These disturbances can accelerate the disappearance of species and create opportunities for the establishment of new species (FAO, 2007), while the ecosystems of arid and semi-arid regions will be strongly affected (Thornton and Herrero, 2009). Studies have shown that changes in temperature and rainfall in the future will often modify and limit the direct effects of CO_2 on plants (IPCC, 2007).

The geographical situation of Cameroon, characterized by three main climatic types, makes that certain regions of the country like the Far-North exposed to the effects of the changes and the climatic variability. With increasingly high temperatures and the distribution of increasingly variable and unpredictable rainfall in this part of the country, its biodiversity will be permanently affected. On the other hand, following the droughts of the 1970s and 1980s, the rescue operation Waza launched by the Cameroonian State consisted of the digging of 17 ponds and boreholes in the Park in addition to the 50 existing ones. This palliative is still insufficient given the persistence of the water problem in this Park (Zourmba, 1993). Thus, the Cameroonian Government, under the financial assistance of the Dutch Cooperation and the WWF, set up the Waza Logone Project in 1992, which aims to restore the Waza Logone Plain (Saleh, 2007). The rehabilitation began in 1994 with the opening of two tributaries of the Logone River. These are Logomatya and Aréitékélé in 1994 and 1997, respectively. This double opening has flooded more than 30% of the plain in general and more than 60% of the park (Scholte, 2005) over an area of about 300 km² (Ledauphin, 2006). This has led to positive results on resources with the availability of pastures and watering points for several months in the dry season in the park (Saleh, 2012). In 2002, the project came to an end without any concept of monitoring or learning. Therefore, the great embellishment observed was only of short duration because the situation has changed to its former state. Since the degradation of climatic parameters (rainfall and temperature) is partly responsible for the decline of the biodiversity of the park, it is important to understand how the populations living near this protected area perceive the changes in their immediate environment.

On this background, this study aims to contribute to a better understanding of the dynamics of biodiversity of the park in relation to the perception of local populations.

MATERIALS AND METHODS

Study site

The Waza National Park is located in the Far North Region of Cameroon, between latitude 11° 03 'and 11° 30' N and longitude 14° 20 'and 14° 66' E, close to Nigerian border 10 km (west) and Chadian border 20 km (east) (MINEF, 1997). The Waza National Park is part of the vast Waza Logone Plain covering 8 000 km^2 (Figure 1). The climate is semi-arid and three seasons are distinguished: a rainy season from June to October; a dry and "cold" season from November to February; a dry and hot season from March to June (MINEF, 1997).

The average annual rainfall in Waza varies between 650 and 700 mm. The average annual temperature is around 28°C but can sometimes go down to 18°C in the cold period of November and also reach 45 or 50°C in the shade in March-April. The thermal amplitude is quite high, sometimes reaching 10 to 15°C (Ledauphin, 2006).

Although the park does not contain any permanent watercourse, hydrology is very complex and decisive, particularly with regard to a large part of the vegetation (Vanpraet, 1977). The inflow of water goes through two main ways: the mayos (temporary streams), coming from the Mandara Mountains and the flood waters coming from the overflow of the Logone River and its branches, the Logomatya and the Loromé Mazra.

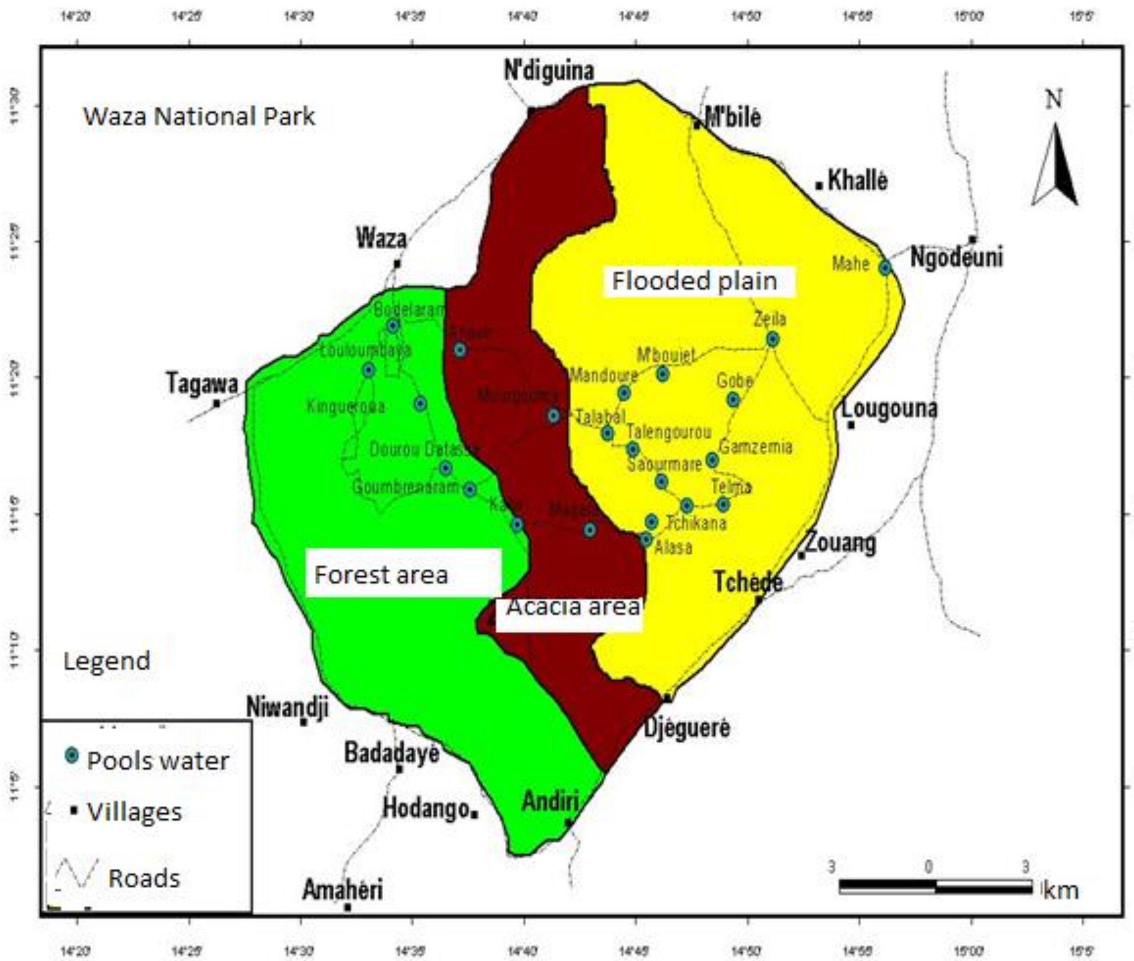

Figure 1. Map of location of the study site.
Source: Ledauphin (2006).

Five types of soil are distinguished in the park from West to East, which are ferruginous soils, planosols, vertisols, hydromorphic soils, anthropogenic soils that are elevated or mounds, signs of an ancient civilization called "Sao Civilization". Soils disturbed by human activity are sandy-clayey on the surface (Vanpraet, 1977).

The park is of the Sudano-Sahelian type characterized by a thorny steppe of *Acacia seyal*, littered with *Balanites aegyptiaca* and rich in annual and perennial grasses (Saleh, 2005). According to White (1986), the Waza National Park is located in the regional center of Sudanese endemism, specifically straddling two vegetation units. The western part of the park is characterized by undifferentiated Sudanian forest (Sudanese forest and savannah with dominant Combretaceae Family), while the eastern part by a mosaic of edaphic grassland and *Acacia* spp. formations. Many authors classify this vegetation in three main types: a wooded vegetation in the western part of the park, whose main species are *Sclerocarya birrea, Anogeisus leiocarpus, Lannea humilis*; shrub vegetation with *Acacia* species located in the center of the Park, the species are *Acacia seyal*, *B. aegyptiaca*, and some *Piliostigma reticulatum* that announce the floodplain; a grassy plain still called " Yaéré " meadow seasonally flooded covering about 55% of the surface of the park and very rich in perennial and annual herbaceous. The main species are *Sorghum arundinaceum, Hyparrhenia rufa, Oryza longistaminata, Ischaemum afrum, Vetiveria nigritana, Panicum anabaptismum, Echinocloa* species, *Aristida adscensionis, Brachiaria ramosa, Brachiaria xantholenca, Chloris pilosa, Echinochloa pyramidalis, Echinochloa stagnina, H. rufa, Jardinea* species, *Oryza barthii, Panicum maximum, Pennisetum pedicellatum, Setaria pallidifusa,* and *Sporobolus pyramidalis*.

The fauna consists of mammals such as *Loxodonta africana, Panthera leo, Hyppotragus equinus, Gazella rufifrons, Kobus kob, Felis sylvestris, Hyena hyena, Canis aureus*, birds, reptiles and fish.

Data collection

The data collection concerned the acquisition of satellite images of the vegetation of the park on LANDSAT, the number of species affected by climate variability and qualitative data.

Acquisition of satellite images on LANDSAT

To evaluate the vegetation dynamics of this protected area, satellite images on LANDSAT were acquired at the same time of the year (December, respectively for the years 1986 and 2016) through the sites http: //earthexplorer.usgs.gov/ and http://glovis.usgs.gov/ to

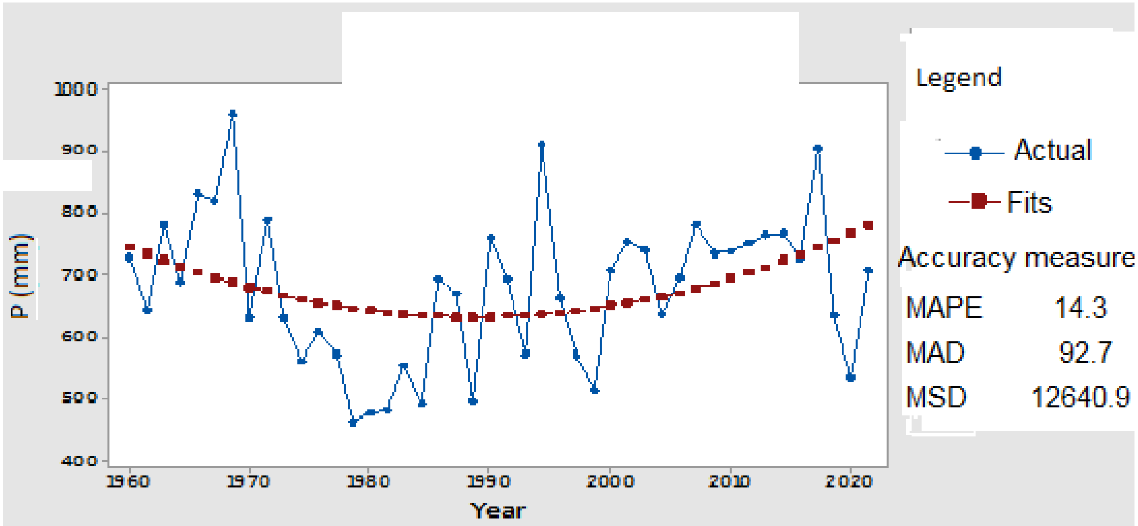

Figure 2. Trend curve of the precipitation of Waza Logone Plain (1960-2020).

reduce problems related to phenological changes in vegetation. Two images were used, namely Landsat 5 TM scenes from 1986 and Landsat 8 OLI scenes from 2016.

Landsat TM scenes from December 1986

The Landsat 5 satellite launched since 1st March 1985 is part of the second generation of Landsat satellites; it is equipped with two multi spectral sensors. This is the MSS sensor whose data acquisition was stopped in 1992 and the TM sensor, tapes were used for the present study. The TM sensor has seven spectral bands and covers an area of 185 km × 185 km. For the 1986 land cover map, the Landsat second grid grid (WRS 2) was used with coordinates 184p52r (Path = 184 and Row = 52) in December 1986. To highlight the theme used here, seven landsat 5 TM strips, bands 2, 3 and 4 which are bands in relation to the canopy were chosen. These tapes allowed us to perform a false color RGB color composition at 4, 3, 2 that is, we assigned band 4 to red, band 3 to green and band 2 to blue.

Landsat 8 scenes from December 2016

This satellite has been launched since 11th February, 2013 and is composed of two instruments namely the OLI instrument (Operational Land Imager) and the TIRS instrument (Thermal Infrared Sensor). The OLI instrument acquires images in nine spectral bands (1 to 9) ranging from visible to infra-red. Seven of these spectral bands were already present on the Landsat 7 ETM + instrument; two additional channels were added, mainly for atmospheric correction (440 nm blue channel) and cloud detection (1380 nm). The TIRS instrument is a two-channel infra-red multi spectral radiometer (Band 10 and 11) that provides data at wavelengths used by older Landsat satellites. For the realization of the 2016 land cover map, the spectral bands of the OLI instrument were chosen. It is mainly a scene from the second landsat grid (WRS 2) with coordinates 184p52r (Path = 184 and Row = 52) from December 2016. For the highlighting of the vegetation cover of the area of interest, bands 3, 4 and 5 were retained in order to make a false RGB color composition at 5, 4, 3 with strip 5 in red, strip 4 in green and strip 3 in blue. It should be noted that these classes were adopted on the basis of the work of Tabopda (2008), which provided for four (4) classes of land occupation: steppe on flooded soil, steppe on clay soil, steppe on sandy soil and steppe on bare soil.

The determination of the number of herbivores affected by climate variability was based on the inventories done by the staff managers of the park.

Qualitative data

The qualitative data were based on questionnaire survey of eighty-four (84) people living near the park, aged at least forty (40) years old. At this age, people might perceive the climate variability for the last forty years. The questions were essentially based on their perceptions concerning the dynamic of biodiversity (flora and fauna) and the variability of the climate in their environment.

RESULTS AND DISCUSSION

Evolution of precipitation

Loth (2004), after an analysis of the pluviometric sequences of the Waza Logone Plain from 1930 to 2000, distinguished five periods: the first period before 1930, characterized by above-average humidity; the second period from 1930 to 1950, characterized by normal humidity, but a little below average; the third period from 1950 to 1969, with above average rainfall; the fourth period from 1970 to 1990, characterized by extreme drought; the fifth period from 1990 to 2000, characterized by a tendency to return to normal with wet years.

Figure 2 shows the trend in precipitation between 1960 and 2020, based on climate data from the study area.

The evolution of the curve indicates two main trends: a decrease in precipitation from the 1970s to the beginning of the 1990s, in line with the results obtained by Loth

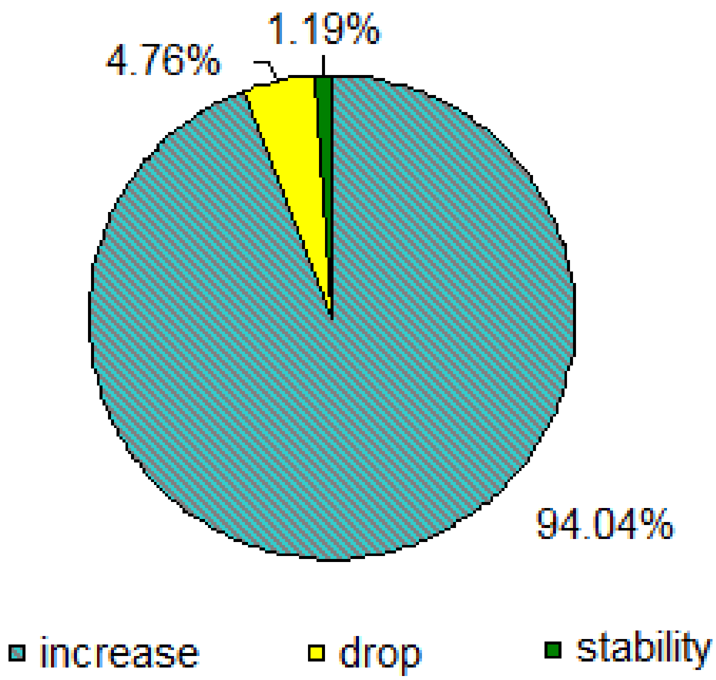

Figure 3. Perceptions of riparian populations of rainfall trends.

(2004); a gradual increase in precipitation from the 1990s to 2013, again in line with the results obtained by Loth (2004).

Abdou (2010) citing Salé (2011) states that this precipitation evolution in the Waza Logone Plain corroborates the results obtained in the other West African Sahelian Sudano regions. According to the same author, the trend in precipitation growth observed in this area since the 1990s is due to a sudden alternation between dry years and wet years. Sighomnou (2002) analyzed the data from 1960 to 2000 in the area and showed that rainfall is steadily declining, and is estimated at around 25%, despite the appearance of the trend of growth indicated by the curve. However, as in all other dry African regions, the main effect is the decrease and the great variability of rainfall, and also the strong evaporation of the waters following the rise in temperatures which drastically reduced the height and duration of floods (Sighomnou, 2002). The same author indicates that it has been shown that in this plain, precipitation fell by about 25%, and floods by about 60% between 1960 and 2000 following the decrease of precipitation in the upper part of the basin.

Overall, the decrease in rainfall and floods, and the increase in temperatures in the area have resulted in the drying of the surface waters of the ponds and rivers.

Perceptions of riparian populations of rainfall trends

The riparian populations mainly perceive the decrease in rainfall which corroborates the precipitation trends in the Waza Logone Plain obtained from the scientific data (Figure 3). Similar studies conducted in Senegal have produced consistent results (Mertz et al., 2009a), where the majority of people (94.04%) perceive a drop in the amount of rain in the last 30 and 40 years, but contrary to the work of Ouoba (2013) conducted in northern Burkina Faso, with contrasting results, with 40% of local populations reporting increased rainfall. The author explains that this contrast can be explained by the fact that on the one hand, the vision of those who mention the decrease of rainfall, can be influenced by the decrease in the number of rainy days especially in August. On the other hand, the vision of those who mention an increase in the quantity of rainfall is in agreement with the analysis of the evolution of the rainfall of the last 30 and 40 years.

Scientific vision of the evolution of temperatures

In the Waza Logone Plain, it is shown from the study carried out by Sighomnou (2002) that temperatures are gradually rising and the high water evaporation estimated by Delclaux (2008) citing Salé (2011) at about 12 km³ (for about 13 km³ of rainfall), would be the cause of the rapid decline in floods (Figure 4).

The trend of this temperature curve, obtained from the zone data, indicates that the temperatures are gradually increasing. These results are consistent with the previous results obtained by Sighomnou (2002) in the area, and the IPCC (2001) shows that this upward trend of

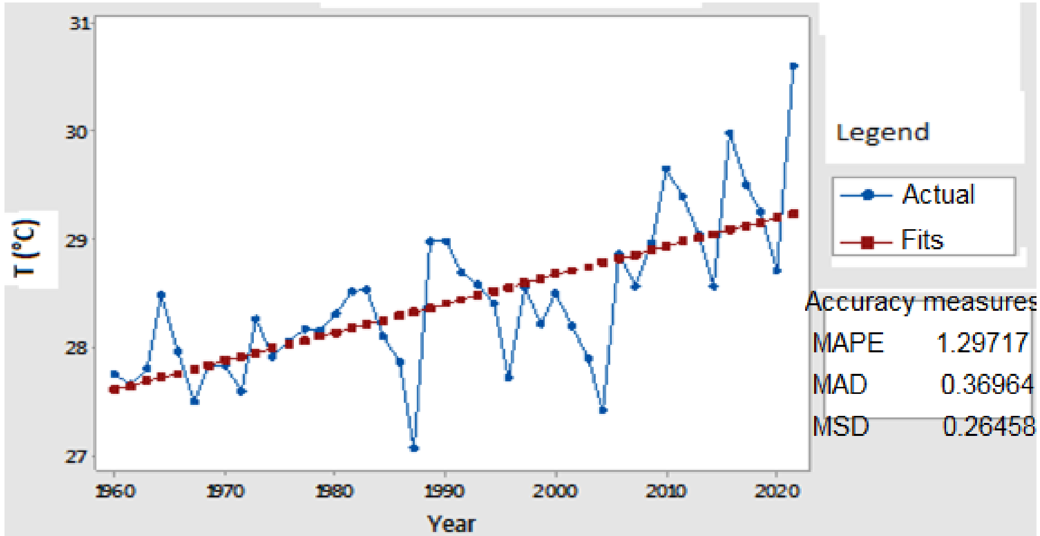

Figure 4. Trend of the evolution of the temperature.

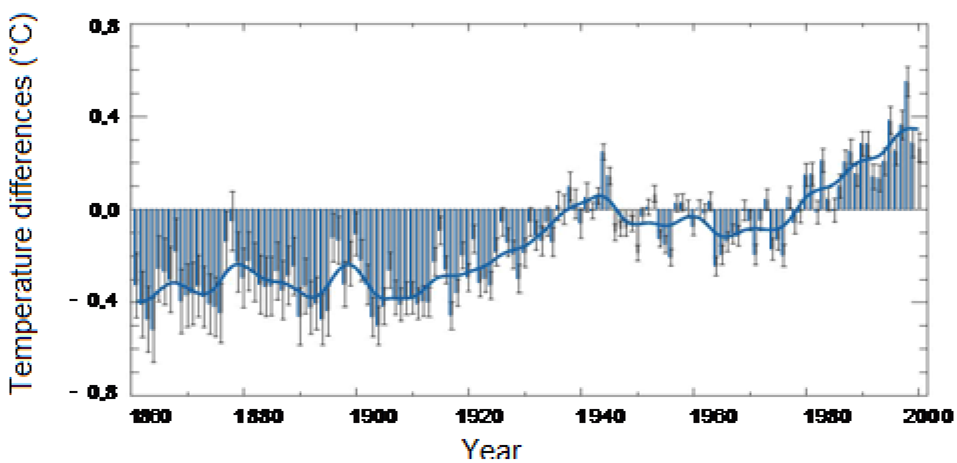

Figure 5. Variation in temperatures at the earth's surface from 1960 to 2000.
Source: IPCC (2001).

temperatures was observed on the whole planet between 1960 and 2000 (Figure 5).

Perceptions of local populations on the evolution of the temperatures

The increase in temperatures in the area is the perception of the majority of local populations (90.47%) (Figure 6), which corroborates the evolution of the temperatures obtained from the scientific data.

The perceptions on the evolution of the temperature reveal that the populations attribute these causes mainly to natural phenomena and to divine wrath. It appears very weakly an implication of the anthropic action. A similar study conducted by Tschakert (2007b) in Senegal showed that populations also mention the mismanagement of the environment and natural phenomena as factors of climate change. In sum, the reasons for the evolution of climatic parameters are generally perceived by the interviewees of the six sample villages as natural causes and divine punishment. A study carried out in the same climatic zone of Burkina Faso leads to the same conclusion (Kabré, 2008).

Scientific vision of the impacts of climate variability on wildlife

Figure 7 shows the evolution of the main herbivorous of

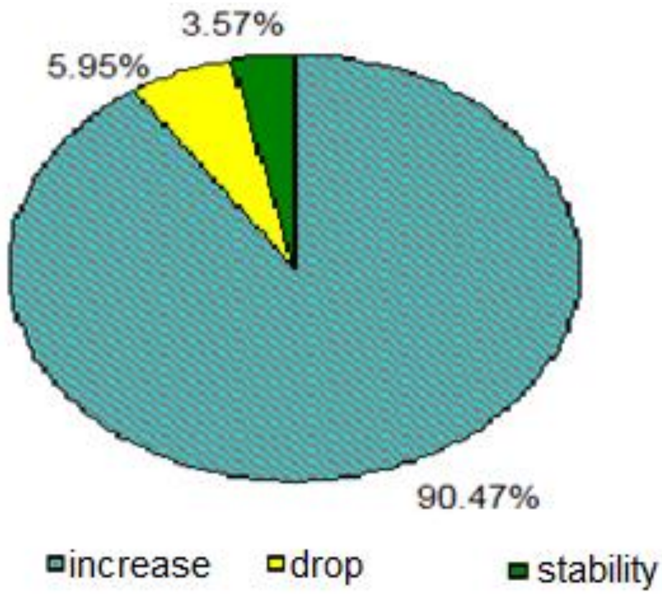

Figure 6. Perceptions of local populations on the evolution of the temperatures.

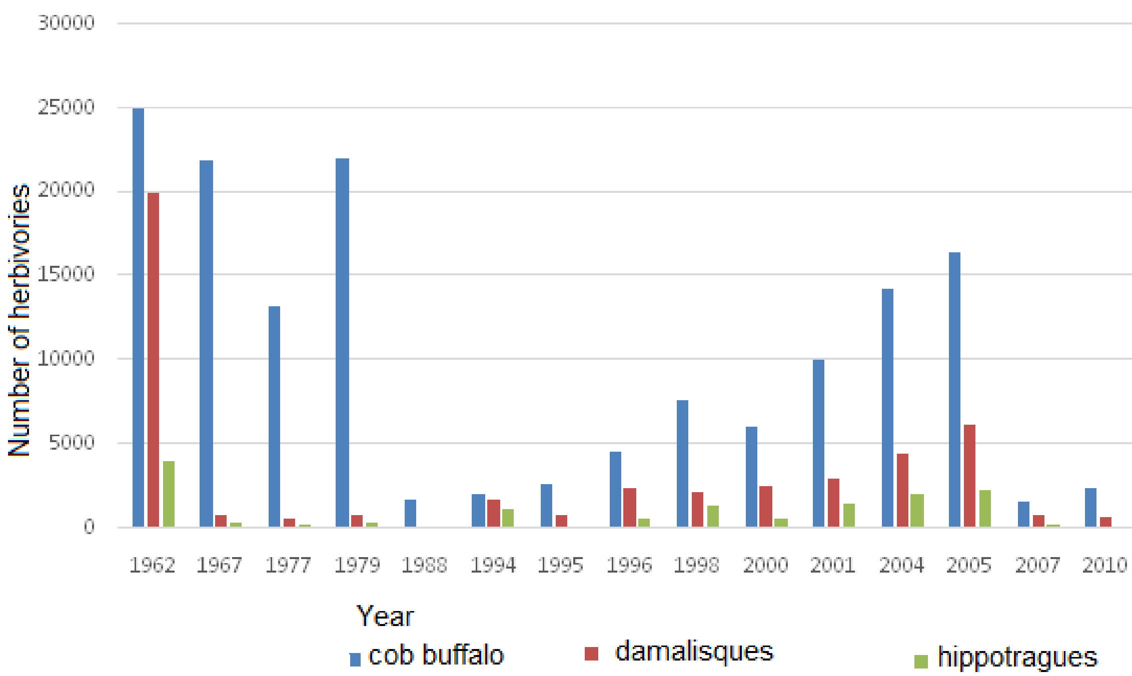

Figure 7. Evolution of three main herbivorous of Waza National Park.

the park. This evolution shows three brutal falls in 1967, 1988 and 2007. The fall in cob buffalo populations is greater than that of the other species because of their vulnerability linked to the high daily watering frequency (3 to 4 times/day) (Saleh, 2012). During the training period, only 4 out of 17 artificial pools still contained water. All natural pools have dried up. Saleh (2012) stated that in 1988, the sharp drop in numbers was caused by the drought where 400 carcasses of Cobs were counted on the edge of dry pools. At this same time, only 1000 Cobs were identified (Vanpraet, 1977). Concerning the other herbivorous that are the Hyppotragues and the

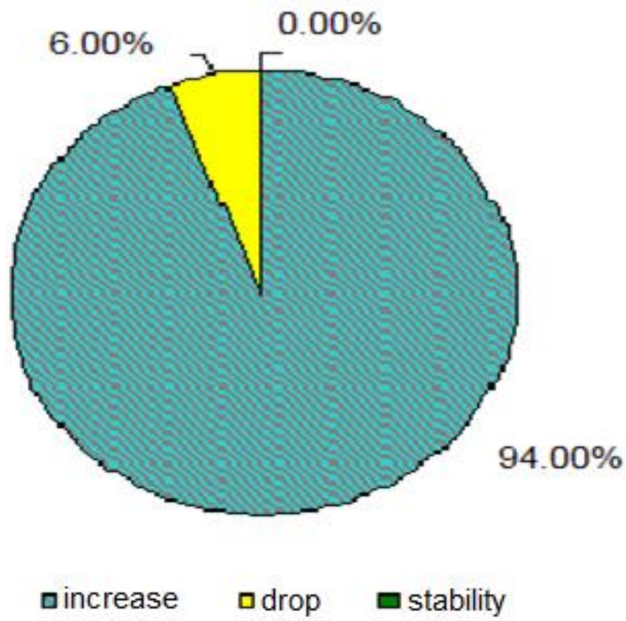

Figure 8. Perception of local populations of the impacts of climate variability on fauna.

Damalisques, the fall in their numbers between the years 1960 and 1970 can be explained according to Scholte (2007) by the first major drought after a decade of heavy rains during which these antelopes left the protected area and became vulnerable through persecution and contact with domestic livestock. He added that contrary to what one thinks, the insufficiency of the flood of the Waza Logone Plain due to the dam of Maga is not the cause of their decline but can be a constraint to their reconstitution.

At the level of the large fauna of the park, the immediate impact of these climatic modifications is the disappearance of species such as the Cobe defassa (*Kobus ellipsiprymnus*), the Bubale (*Alcelaphus buselaphus*), the Buffalo (*Syncerus cafer*), the Panther (*Panthera pardus*), and the Cheetah (*Acinonyx jubatus*) (Saleh, 2012). Going in the same direction, Ndjidda (2012) pointed out that the Redunca (*Redunca redunca*), the Serval (*Leptailurus serval*) have not been seen in the park since 2009. The climatic variability, over time, has negatively impacted on the evolution of the fauna of this protected area. IPCC (2014) stated that increasing magnitude of warming increase the likelihood of severe, pervasive and irreversible impacts on biodiversity, and some risks of climate change are considerable at 1 or 2°C above preindustrial levels.

Perception of local populations of the impacts of climate variability on wildlife

The decline of the fauna in the protected area is the perception of the majority of riparian populations (94.00%) (Figure 8). It appears that wildlife species in the park have all undergone a regressive evolution, but that this trend is to different degrees depending on the vulnerability of each species. This is consistent with the evolution of some species of fauna found in the various counts; in this case the antelopes present an evolution of sawtooth curve (Saleh, 2012). Also, the local populations cite antelopes (Cob buffalo, Damalisques, Hyppotragues) as the species that have undergone great decay. Beside the antelopes, felines like lion and hyena have also seen their number dropped because of the decrease of their main prey indicates the populations. Overall, people have a good perception of the decline of wildlife.

Scientific vision and perceptions of local populations of the impacts of climate variability on the vegetation of Waza National Park

Landsat images from 1986 and 2016 were used to determine four classes of land cover (Figures 9 and 10). The vegetation cover consists mainly of steppes (steppe on flooded soil and steppe on clay soil), soil more or less vegetated and sand or bare soil. The differentiation between the various thematic classes (soil occupation units) is generally significant for the 1986 and 2016 images. The values of the Kappa coefficient are globally high for the images of the two scenes.

State of occupation of soil in 1986

Supervised classification was performed by QGIS 2.17 and ENVI 4.5 software. The result is shown in Table 1.

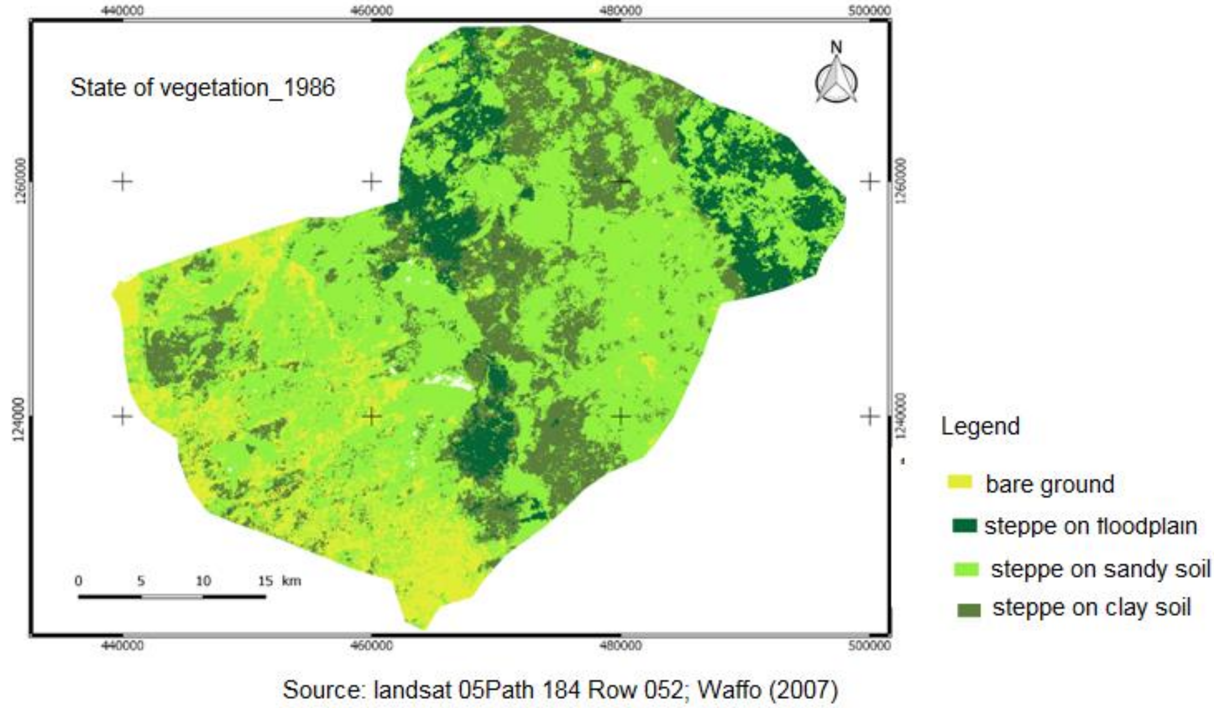

Figure 9. Map of occupation of soil of Waza National Park in 1986.

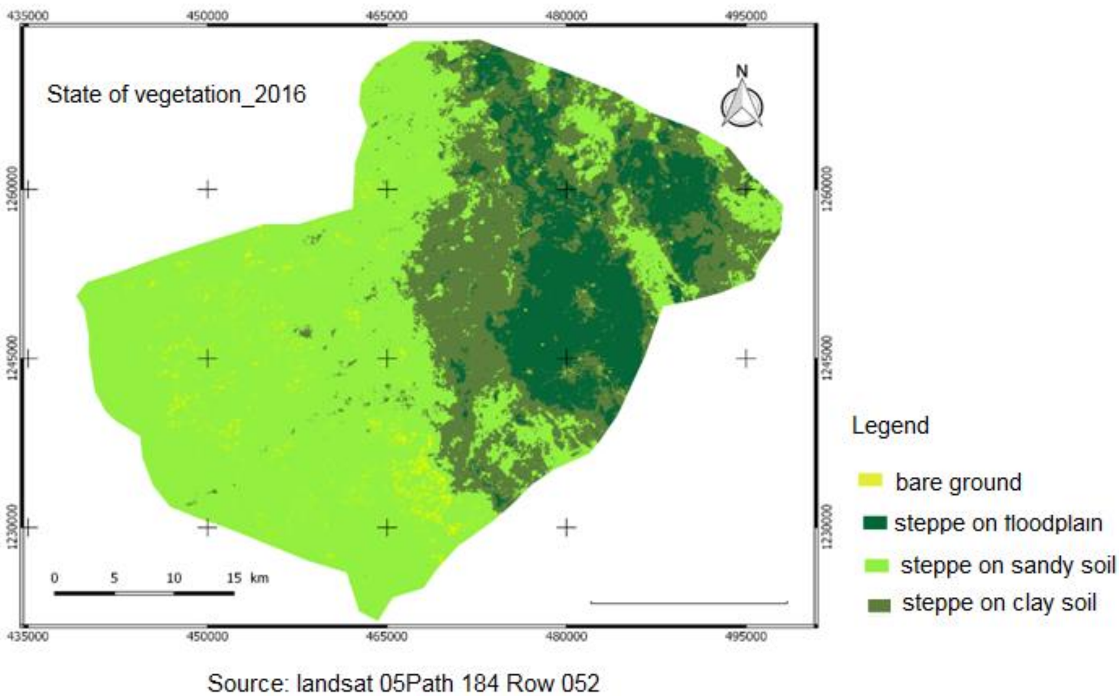

Figure 10. Evolution of soil occupation between 1986 and 2016.

The confusion matrices indicate that there was no confusion between the different classes when classifying the 1986 image. All units of land occupancy were well classified. The pixels are well ranked with percentages

Table 1. Matrix of confusion from the supervised classification of 1986.

Class	Steppe on floodplain	Steppe on clay soil	Steppe on sandy soil	Steppe on bare soil	Badly ranked
Steppe on floodplain	131	3	0	18	0
Steppe on clay soil	1	114	99	92	40
Steppe on sandy soil	0	0	0	0	72
Steppe on bare soil	0	0	2	0	0
Total	132	117	101	110	112

Table 2. Areas of land occupation classes in 1986.

Land cover class	Corresponding area (ha)	Percentage by total park area (%)
Steppe on floodplain	19 170	11.27
Steppe on clay soil	25 560	15.03
Steppe on sandy soil	37 800	22.23
Steppe on bare soil	11 970	7.04
Total	94 500	55.57

Table 3. Confusion matrix from the supervised classification of 2016.

Class	Steppe on floodplain	Steppe on clay soil	Steppe bare soil	steppe on sandy soil	Badly ranked
Steppe on floodplain	213	0	0	0	0
Steppe on clay soil	0	145	139	0	0
Steppe bare soil	0	0	0	147	0
Steppe on sandy soil	0	0	0	0	140
Badly ranked	0	1	0	0	2
Total	213	145	139	147	140

between 92.52 and 100%. However, some errors of commission and omission occurred during the classification. The errors are mainly made in steppe classes on clay soil and bare soil with values of 21.36 and 12.28% respectively.

Area of different classes in 1986

The supervised vegetation classification in 1986 identified four (04) occupancy classes with corresponding areas (Table 2).

The park is covered by very sparse vegetation. The steppe on sandy soil is the most dominant with an area of 37 800 ha and represents 22.23% of the total area of the park. Subsequently, the steppe on clay soil with an area of 25 560 ha for 15.03% of the area; the steppe on flood plain with 19 170 ha for 11.27%; bare soil with little vegetation covers an area of 11 970 ha, for 7.04% (Figure 9).

Overall, the 2016 image confusion matrices indicate that there was no significant confusion between classes during classification. Steppe classes on floodplain, steppe on clay soil and steppe on sandy soil have more than 80% of the well-ranked pixels. Errors of commission and omission occurred during classification. Commission and omission errors are respectively 11.66 and 10% for the bare soil class (Table 3).

In 2016, the steppe class on clay soil is the most dominant vegetation with an area of 29 610 hectares, for 17.41% of the total area of the park. There was a regression of vegetation between the two dates since the class of bare soil with little vegetation comes second with an area of 13 230 hectares, for 7.78% of the park. The steppe on floodplain was 11 880 hectares, for 6.98% and finally the steppe on sandy soil with an area of 10 260 hectares, for 6.03% (Table 4).

The diachronic analysis of land use changes in 1986 and 2016 in Waza National Park reveals that all units experienced increasing or decreasing changes between 1986 and 2016. However, the analysis shows a general trend towards degradation of vegetation between 1986

Table 4. Areas of land occupation classes in 2016.

Classes of land cover	Corresponding area (ha)	Percentage by total park area
Steppe on floodplain	11 880	6.98
Steppe on clay soil	29 610	17.41
Steppe on sandy soil	10 260	6.03
Steppe on bare soil	13 230	7.78
Total	64 980	38.21

Table 5. Evolution of vegetation between 1986 and 2016.

Elements of soil occupation of the park	1986		2016		Evolution 1986-2016	
	Area (ha)	%	area (ha)	%	Area (ha)	%
Steppe on floodplain	19 170	11.27	11 880	6.98	-7 290	-4.29
Steppe on clay soil	25 560	15.03	29 610	17.41	4 050	2.38
Steppe on sandy soil	37 800	22.23	10 260	6.03	-27 540	-16.20
Steppe on bare soil	11 970	7.04	13 230	7.78	1 260	0.74
Total	94 500	55.58	64 900	38.17	-29 600	-17.41

and 2016 (Figure 10).

There are cases of progression and regression of plant formations between 1986 and 2016 (Table 5). The increases observed concern steppe classes on clay soil with a rate of 2.38% and bare soil with little vegetation with growth rates of 0.74%. The increase of the steppe on clay soil, which refers to the Acacia zone of the park, is explained by the adaptation of these species to the arid climatic conditions of the study area and is favored by zoochoria. While the increase of bare soil with little vegetation results from the decline of the original vegetation due to the climatic conditions more and more execrable. The degradation of this plant cover leads to the appearance of bare soils which are thus exposed to bad weather. Adverse effects include multiple consequences such as the formation of shallow crusts, increased runoff and lack of infiltration, leading to a gradual decline in groundwater levels (Ouoba, 2013). Regressions affected steppe classes on floodplain and steppe on sandy soils with regression rates of -4.29 and -16.20%. These results are contrary to those of the work of Tabopda (2008) carried out between 1986 and 2001 in the area which used the scenes of April; then those of December were used, and which showed rather the regression of the classes of steppe on clay soil and bare soil with little vegetation and steppe class progression on floodplain and steppe on sandy soil.

Scientific vision of the impacts of climate variability on vegetation

Predictions from climatologists for the next century indicate global warming, a change in precipitation patterns and climate variability. These adverse effects of climate change and variability can be a major threat to living organisms, directly affecting species or altering their habitats (Chidumayo, 2008; Donfack, 2011). It was noticed by Scholte (2005) an invasion of the park by annual grasses, not palatable by wild animals and decaying rapidly after the end of the flood, at the expense of perennial grasses. The regression of park vegetation is compared by Sighomnou (2002) to increased desertification of this protected area. A similar study in the Sena Oura National Park in Canton Dari in Chad showed that successive droughts have caused the drying up of water sources and drainage of lowland and the destruction of the habitat of fauna species (Bora and Somba, 2014).

Perceptions of local populations on the impacts of climate variability on vegetation

Figure 11 gives the distribution of the different perceptions of the riparian populations on the evolution of the vegetation of the park. The decline of vegetation is the perception of the majority of riparian populations. However, the results of the survey reveal a perception of the improvement of vegetation cover at a proportion of 30.95%. The vast majority of responses in favor of vegetation improvement come from village populations on the plain side. In fact, in the face of the receding floods from year to year, a few feet of woody species are growing in the grassy carpet of the plain. This situation makes these populations believe in an increase in vegetation. But the spatial analysis shows the opposite with a regression of 7 290 ha.

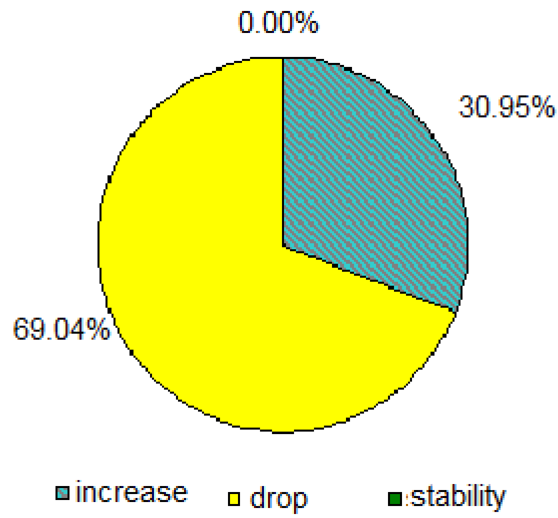

Figure 11. Perceptions of local populations on the evolution of vegetation.

Overall, the perceptions of local populations show that they have a good perception of the evolution of vegetation cover. This is consistent with the results of the diachronic analysis of land use by satellite images. These results show that vegetation of Waza National Park decreased by 17.41% from 94 500 to 64 900 ha, or 29 600 ha for cover land use units. The riparian populations mention as major causes of the decline of the vegetation cover: the irregularity of the rains, the increase of the heat and the receding of the floods with 96.42, 79.76 and 66.66%, respectively. The other cause cited by riparian populations is bush fires (25%). Added to this is the strong wind which, according to 22.61% of the populations in the six sampled villages, uproots the trees. The majority of the interviewees in the six villages said that there was a trend of decreasing vegetation cover due mainly to irregular rainfall, increased heat and reduced flooding. This same observation is noted in the works of Wezel et al. (2006) as cited by Ouoba (2013).

The decline in vegetation cover highlighted by the interpretation of satellite images is confirmed by the local populations living in this area. Populations have even pointed out that climatic variability has favored the simple disappearance of certain woody species such as *Diospyros mespiliformis, Acacia polyacantha, Borassus aethiopum* and *Ficus rubiginosa*. The analysis of the evolution of land use in the park between 1986 and 2016 shows a general tendency towards degradation. The main causes of degradation include: irregular rainfall, increased heat, receding floods, bush fires and strong winds. The assessment of the perception of local populations on the evolution of biodiversity shows they have a good perception of the evolution of different components of the biophysical environment, especially the vegetation cover. This is in agreement with the results of the analysis of the ground occupation by the satellite images.

Conclusion

Climate change and variability is one of the major ecological challenges of the 21st century in the Waza Logone Plain of the Far North Region in Cameroon. The physical environment in this area has almost completely deteriorated as a result of declining rainfall and rising temperatures. The overall objective of the study was to show the dynamics of biodiversity in relation to the climatic variability of the Waza National Park located in the heart of the Waza Logone plain. The approach taken to conduct the study combines the use of survey and field observation data, modeling of climate data through MINITAB 17 software, analysis of wildlife census data, and digital analysis of satellite images using ENVI 4.5 and QGIS 2.17 software.

The results showed a regressive trend of precipitation between 1970 and 1990, then a gradual trend from 1990 to 2004. The vast majority, that's 79% of the populations perceive a negative evolution of the various climatic parameters, which is consistent in the majority of case with meteorological data analyzes. The temperatures are gradually increasing according to the scientific vision and the perceptions of the populations. The general trend of biodiversity evolution (fauna and vegetation) over the last forty years is to the continued degradation of Waza National Park. Landsat images from 1986 and 2016 were used to determine four classes of land cover. The vegetation cover consists mainly of steppes (steppe on flooded soil and steppe on clay soil), soil more or less vegetated and sand or bare soil. The differentiation between the various thematic classes (soil occupancy units) is generally significant for the 1986 and 2016 images (P<0.05). The values of the Kappa coefficient are globally high for the images of the two scenes.

Recommendations were made for the restoration of the park's biodiversity, including the construction of water ponds and Cartesian wells, the improvement of the load capacity of the park in fodder, the enrichment of the park with woody species.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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