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Climate Trends and Changes in Biodiversity in the Comoé National Park (North-East Côte d'Ivoire)

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ABSTRACT

The Comoé National Park, with a surface area of 1,149,450 hectares, stands out for its exceptional biodiversity. However, in the context of current climate change, marked by the gradual degradation of natural resources, it is crucial to understand how this changing climate is influencing this biodiversity. The study therefore aims to show the impact of current climatic conditions on changes in biodiversity within Comoé National Park. The methodology adopted is based on a combined analysis of climatic data, vegetation indices and observations of animal species in the park, using statistical and geomatic approaches. A diachronic analysis was used to study the relationship between climate dynamics and changes in recent plant and animal species, using correlation tests. The results reveal a significant decrease in rainfall and humidity, as well as an increase in temperature. Analysis of Thom's discomfort index and the improved vegetation index indicates a deterioration in conditions for biodiversity to flourish, accentuated by the climatic irregularities observed.

Keywords: Comoé Park, Climate trends, Degradation, Biodiversity

INTRODUCTION

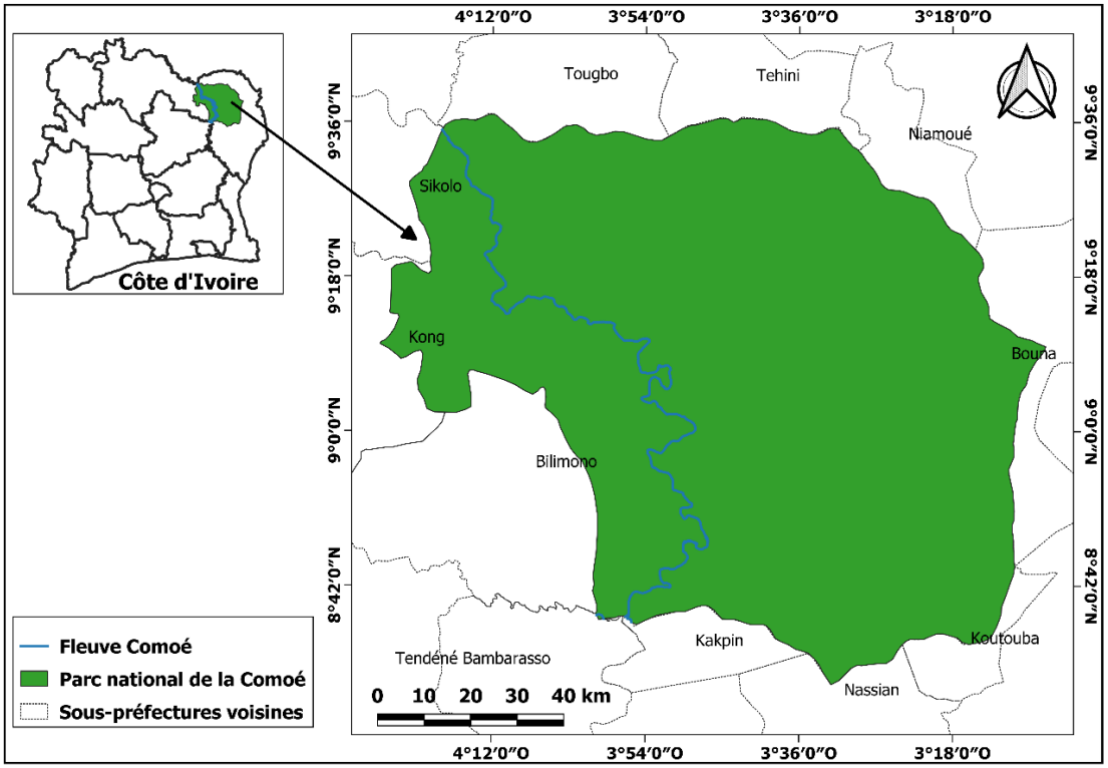
Global warming, a factor in environmental degradation, is causing major upheavals in natural ecosystems. The climate determines the presence of natural species in a given environment. But these days, climate dynamics are having an impact on water resources and on plant and animal diversity as a whole. For example, it is leading to the decline and disappearance of existing plant species and the disruption of the migration cycles of certain bird species. The reduction in river levels following droughts has an impact on the aquatic organisms that live there (MDDEP, 2011, p. 3). Côte d'Ivoire's natural environment is rich in resources, and the Comoé National Park is a good example of this. It is therefore important to consider the real impact of irregularities in local climate parameters on plant and animal species within this park. In other words, how does the current climate trend impact on the evolution of biodiversity in Comoé National Park? The study therefore aims to show the impact of current climatic conditions on the evolution of biodiversity in the Comoé National Park. The development that follows will lead us first to characterise the climatic trend in the Comoé National Park between 1960 and 2020. Secondly, a diachronic analysis will be made of changes in the vegetation index in relation to the local climate. Finally, it will be important to analyse changes in the state of health of certain animal species in the park in relation to the climatic environment, using Thom's comfort index.

MATERIALS AND METHODS

Presentation of the Study Area

It was planned as early as 1926 and founded in 1953 under the name of Bouna Reserve. The Comoé National Park was officially given this name by decree no. 68-81 of 9 February 1968 (OIPR-2024, p. 30). It is located in the north-east of Côte d'Ivoire between latitude 8°30-

9°37 North and longitude 3°07- 4°26 West (map 1). The Comoé National Park (CNP) is one of the largest parks in West Africa, covering an area of 1,149,150 hectares. It is a region covered mainly by savannah. The Comoé River, however, is flanked by gallery forests for most of its length, providing an ideal habitat for a wealth of wildlife.



Map 1: Location of Comoé National Park

To date, it has 620 plant species, 135 mammal species, 35 amphibian species, 60 fish species, 71 reptile species and the three crocodile species (UNESCO, 2017, p. 1). Comoé National Park is drained by a fairly dense hydrographic network. It is a composite of several watercourses of various types, including the Comoé River, the main river, and the Iringou, Kongo and several other tributaries. This network also includes ponds of varying sizes, enabling animals to drink without difficulty. The park's wealth of waterholes is an asset for the sedentarisation of animal species (OIPR, 2015-2024, pp. 30-33). It has indurated reworked soils of cuirassed mounds, typical soils with indurations and hydromorphic soils. The climate is of the humid tropical type with a North Sudanian variation. Average annual rainfall is between 900 and 1,200 mm, with an average of 1,084 mm per year. The average annual temperature ranges from 26°C to 27°C. The dry season is very marked and can last up to 6-7 months in the park. According to Eldin Guillaumet and Adjanohoun (1971, p. 19), relative atmospheric humidity averages 60%. It reaches 90% in the rainy season.

Data

Study tools and data

A number of data sets were required to achieve the research objectives. Firstly, *climatological data* from SODEXAM (Société de Développement et d'Exploitation Aéroportuaire, Aéronautique et Météorologique). The data covers rainfall, temperature and relative humidity from 1981 to 2020. MODIS *satellite images* were then required. These images are from 2000 to 2020, with a regular five-year interval (2000, 2005, 2010, 2015 and 2020). *Statistical data on plant species* was also collected from OIPR-DZNE (Office Ivoirien

des Parcs et Réserves de la Direction Zone Nord-Est). Specifically for animal species, data were collected on a number of mammal and bird species and their habitats in Comoé National Park over three years (2010, 2014 and 2016). Finally, *primary field data* from direct observations and essentially qualitative individual interviews were also collected. Mobile phones were used for filming. Interviews were used to gather testimonies from resource persons, in particular OIPR-DZE agents.

Methods

The different treatment methods were classified according to the operational objectives of the study.

- *To characterise local climate trends*

The monthly rainfall coefficients calculated can be used to characterise the rainfall regime. To highlight rainfall patterns, the average value observed is related to what would be the monthly water level if the rain were distributed rigorously equally for each day of the year. The formula is as follows: **Cm=K.Pm/p** with**: Cm**=rainfall coefficient**, Pm**=high monthly rainfall in mm, **P =** high annual rainfall in mm**, K =** the inverse of the number of days in the month over the number of days in the year (Kanga, 2016, p.113). There is also the stationarity of the rainfall and temperature series, which has been analysed using the Pettitt test (1979). The absence of a break in the series (Xi) of size N constitutes the null hypothesis. Its formula is defined by: Ut,N defined by: $\boldsymbol{Ut, N = \sum_{j=1}^{t} \quad \sum_{j=t+1}^{n} Dij}$, where: **Dij=sgn** (Xi - X j); **sgn**(X)=1 if X>0; **sgn**(X)=0 if X=0; **sgn**(X)=-1

- *To analyse the impact of climate on the vegetation of the CNP*

Geomatic tools were used for this analysis. The processing consisted of making maps showing the evolution over time of the vegetation in the Comoé National Park. Several colour compositions were used for this purpose. The improved vegetation index (EVI) is defined by the following formula: $\boldsymbol{EVI = 2,5 \times \frac{(PIR-R)}{(PIR+6R-7,5B+1)}}$, where: **PIR** (Near Infra-Red): reflectance in the near infra-red band, **R** (Red): reflectance in the red band, **B** (Blue): reflectance in the blue band (Huete, 1997). In this study, it was used to observe the influence of climate on the vegetation of the Comoé National Park.

- *To analyse the influence of climate on the fauna of the CNP*

Thom's discomfort index (THI, 1976) was used to show the effects of temperature and humidity on animals. The ITH is expressed by the following equation:

$\boldsymbol{ITH = T - 0,55 \times (1 - \frac{HR}{100}) \times (T - 14,5)}$**,** with**: ITH=** Thom's discomfort index, **T=** temperature (T°C), **H=** humidity (H%)

Table 1: Interpretation of the ITH

ITH (Thom's Discomfort Index)	Atmosphere
ITH ≥ 30	Hot
] 29,9 to 26,5]	Very hot
] 26,4 to 20,0]	Hot
] 19,9 to 15,0]	Comfortable
] 14,9 to 13,0]	Fresh
]-12,9 to -1,7]	Cold
]-1,8 to -9,9]	Very cold
ITH ≤ -10	Extremely cold

Source: Kone, 2022

The quantitative and qualitative data from the animal species surveys were processed using Excel software.

RESULTS

Characterisation of Climate Trends in the Comoé National Park (CNP)

Characterisation of seasons in the CNP from 1981 to 2020

Figure 1 shows monthly rainfall trends in Comoé National Park from 1981 to 2020. From May to October, the rainfall indices are above 1, with a peak in September (1.93). This period corresponds to the rainy season. On the other hand, from November to April, the indices are below 1, indicating the dry season, with particularly low values in January (0.04) and December (0.06). It can therefore be said that Comoé National Park is characterised by an acute unimodal regime with two seasons: a wet season and a dry season.

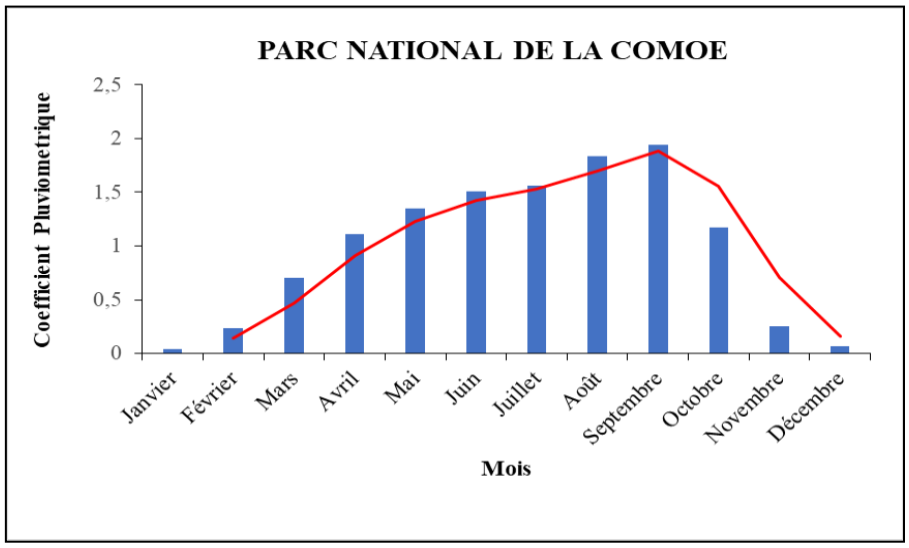


Figure 1: Rainfall pattern in the CNP from 1981 to 2020

Characterisation of rainfall trends in the CNP from 1981 to 2020

The Pettitt test was applied to the interannual rainfall averages and a break in the time series was detected in 1991. This break marks a one-way change in rainfall trends. It attests to the irregularity of rainfall, characterised by a general downward trend. The average before the break was 1166 mm and the average after was 988 mm (Figure 2).

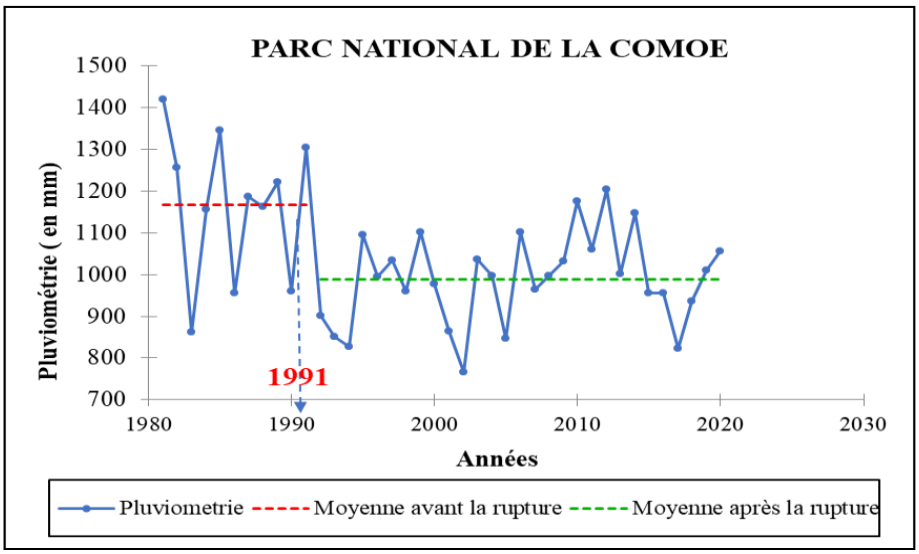


Figure 2: Rainfall trends in the CNP from 1981 to 2020

Characterisation of the temperature trend in the CNP from 1981 to 2020

Temperature trends in the Comoé National Park have shown an upward trend. This inter-annual trend was also marked by constant fluctuations between 1981 and 2020, with a break recorded in 1993. The first sequence (1981-1993) marks the pre-breaking period, with an average of 26.53°C. The second sequence, after the break between 1993 and 2020, shows an average of 27.15°C (Figure 3).

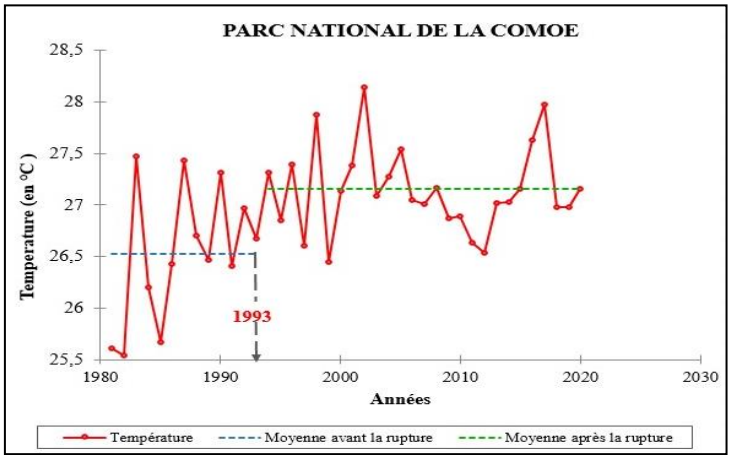


Figure 3: Temperature trend in the CNP (1981-2020)

Influence of Climate Trends on the Evolution of Vegetation in the Park

Relationship between climatic dynamics and seasonal changes in vegetation in Comoé National Park

Figure 4 shows the seasonal evolution of vegetation in Comoé National Park using the Enhanced Vegetation Index (EVI). This analysis reveals two contrasting characteristics of the vegetation over the course of the year. There is less vegetation during the dry season and lush vegetation during the wet season from May to October. Figure 4a shows the dry season (November-April). It shows distressed vegetation characterised by low chlorophyll content. The average EVI here is between 0.11 and 0.4, indicating vegetation under water stress. In contrast, during the wet season, the plant cover is rich in chlorophyll. It is influenced by abundant rainfall and falling temperatures. The EVI during this period fluctuates between 0.31 and 0.60. We can therefore conclude that lower rainfall and higher temperatures influence chlorophyll activity, thus explaining the seasonal changes in plant cover in the park.

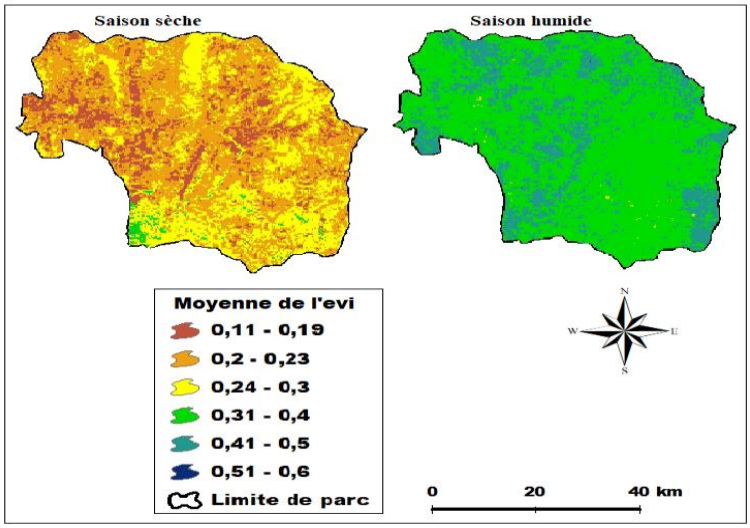


Figure 4: Seasonal changes in chlorophyll activity in CNP vegetation

Relationship between climatic dynamics and interannual changes in vegetation

The correlation between climate and vegetation on a multi-year scale is observed in the Comoé National Park through the dynamics of its floristic exuberance. In this study, the enhanced vegetation index (EVI) was used to highlight the impact of climate on the park's vegetation. Climatic conditions are represented by decreasing rainfall and increasing temperature. This analysis is based on the interpretation of five images taken at regular five-year intervals between 2000 and 2020 (Figure 5).

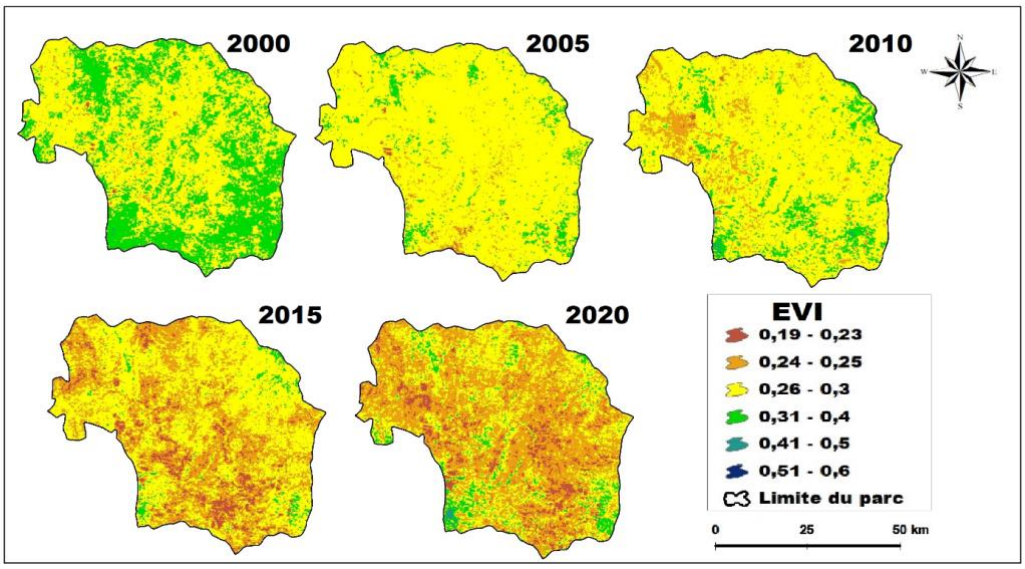


Figure 5: Interannual changes in chlorophyll activity in the vegetation of the CNP from 2000 to 2020

Over the years, the adverse effects of global warming have been felt in the vegetation of Comoé National Park. In 2000, the EVI showed a high value, mostly between 0.31 and 0.40, corresponding to vegetation with good chlorophyll activity. However, in 2005, the EVI mainly showed indices between 0.26 and 0.30. This indicates a decline in vegetation cover between 2000 and 2005. This decline can be attributed to episodes of drought and/or an increase in human activity in the park during the military-political crisis in 2002. Since 2010, there has been a resurgence of vegetation, with an increase in the number of areas with an EVI index greater than 0.31. This increase is due to the various efforts to manage the park properly and to the relative drop in temperatures between 2005 and 2011, accompanied by a slight increase in rainfall. However, between 2015 and 2020, the EVI will be between 0.19 and 0.25 for most of the fleet. The accentuation of global warming, marked by an increase in temperature and a drop in rainfall from 2011 to 2018, is at the root of the decline in chlorophyll activity in the park. It is also important to note the sporadic human incursions into the park despite the protection efforts of the public authorities.

Influence of Climatic Trends on the Evolution of Fauna in Comoé National Park

Trends in the discomfort index (ITH) in Comoé National Park

Analysis of the discomfort index (ITH) has made it possible to determine the state of comfort or discomfort of animal populations in the face of climatic conditions in the Comoé Park. The ITH has an almost constant value. It fluctuates between 22.06 and 26.72 during the year (Figure 6). This corresponds to hot to very hot climatic conditions on the Thom (1976) scale. This situation is particularly prevalent during the dry season (November to April) in the Comoé Park. The high ITH index implies a high temperature to the detriment of air humidity, which is deficient.

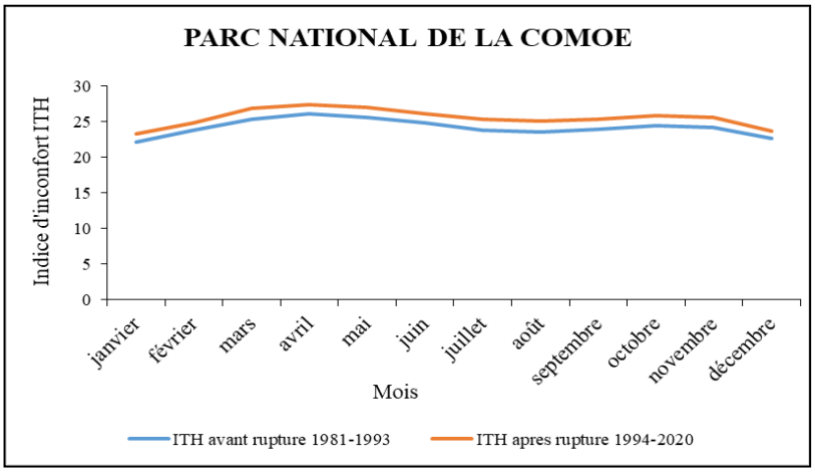


Figure 6: Change in HTI in Comoé National Park (1981-2020)

Figure 6 shows changes in Thom's Discomfort Index (TDI) in Comoé National Park before (1980-1993) and after (1994-2020). The break in rainfall occurred in 1993. The ITH over the two periods shows a similar pattern, with a peak during the months of March, April and May, corresponding to the end of the dry season and the start of the rainy season in the northern Sudanian climate zone that covers the park. Before the break in 1993, the highest indices were between 25.54 and 26.13. This corresponds to a warm climate. However, there is a difference between the two periods, with the post-breakdown ITH showing peak indices of between 27 and 27.34 on Thom's scale. The deterioration in the animals' state of comfort is due to their heavy exposure to harsh weather conditions. This increases their stress levels. High levels of stress in animals have a number of consequences, such as reduced milk production, weight loss, difficult calving, disease and even death in some species considered sensitive to harsh climatic conditions.

Changes in wildlife species in Comoé National Park between 2010 and 2016

The evolution of the animals was analysed in relation to the climate on two-time scales. There is the seasonal and multi-annual time step.

The seasonal migration of animal species occurs periodically. This seasonal migration of animal species in the park can be divided into two, namely migration during the dry season and that during the wet season. This migration is shown in Figure 7.

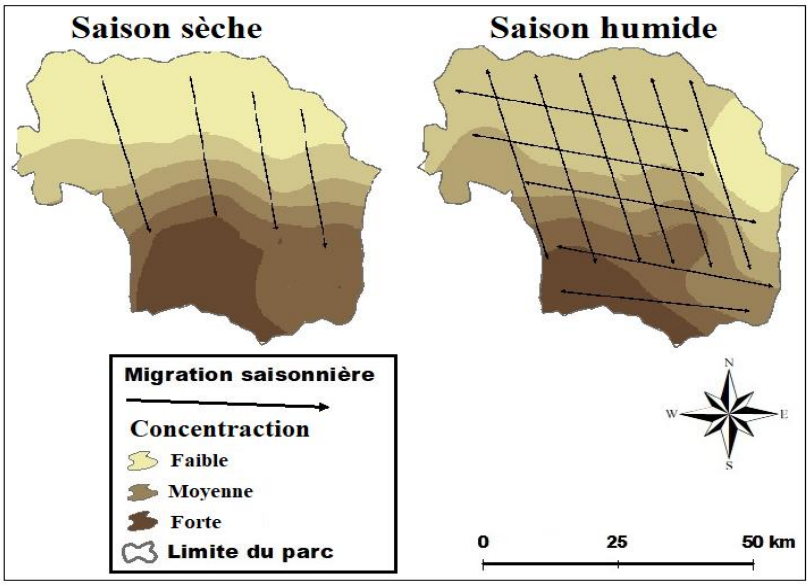


Figure 7: Seasonal migration of animal species in the park

Animal species generally migrate during the dry season from difficult areas to areas of interest. During the prolonged dry season, the Comoé National Park, given its geographical location, experiences a drying up of the grasses and several watering holes, which has an impact on animal diversity. This causes species to migrate towards the park's comfort zones in search of food and water. During the wet season, however, animal species migrate almost everywhere in the park. This is the season of comfort throughout the park. During this season, the rains are abundant, the vegetation covers the empty spaces and the watercourses in the park are drained. Animal migration generally follows a north-south gradient. In the dry season, they migrate from the north to the south of the park. But in the wet season, migration takes place throughout the park.

On a multi-annual scale, Comoé National Park is home to a wide variety of animal species. It has both typical forest and savannah species. However, savannah wildlife species are the most dominant in the park (OIPR REPORT, 2015, p. 110). Table 3 shows changes in animal diversity through the number of presence and loss of different species observed during monitoring in 2010, 2014 and 2016. The results of this monitoring are not eloquent enough. In fact, several losses were recorded. For example, 1,177 individuals were lost from the *hartebeest* population, 742 from buffalo, 543 from cynomolgus, 33 from *redunca* and 11 from duiker.

Table 3: Changes in some CNP species by year interval

Species	2010 - 2014	2014 - 2016	2010 - 2016
Baboon	19	8	27
Bubale	9867	-1177	8690
Buffalo	731	-742	-11
Buffon's cobbler	1529	-543	986
Yellow-backed duiker	7	33	40
Red-flanked duiker	44	74	118
Grimm's duiker	49	43	92
Chimpanzee	265	494	759
Cephalophe. Maxwell	113	-11	102
Black duiker	10	35	45
Harnessed Guib	58	26	84
Hippotrague	227	671	898
Elephant	13	60	73
Patas	100	42	142
Warthog	17	93	110
Bushpig	0	10	10
Redunca	58	-33	25
Cobe Défassa	103	13	116
Ourébi	24	5	29

Source: OIPR reports, 2016

The results of the 2010 monitoring show a low number of animal species. This low number of species is due to several factors, including human activity in general. During the 1998-2011 crisis, park surveillance activities were affected. People were infiltrating the park to carry out illegal activities such as poaching, gold panning and farming. This led to the Comoé National Park being placed on the list of World Heritage in Danger in 2003 (OIPR, 2010, p.24). In 2014, there was an increase in the number of animal species in the park. This positive trend can be explained by the stability of the country from 2012 onwards, which saw the resumption of park monitoring activities by OIPR staff, aided in their tasks by two aerial inventories carried

out with the technical support of the Wild Chimpanzee Foundation (WCF) and GIZ in 2010 and 2014. Since then, management of the park has improved. However, physical and climatic factors are still having a major impact on the development of biodiversity in general and wildlife in particular. According to Major Ouattara Amara of the OIPR, the threat to wildlife species in the CNP is accentuated by global warming. This explains their high-water requirements. Indeed, some species have difficulty withstanding harsh climatic conditions (Plate 1). Between 2014 and 2016, losses were recorded among them despite reinforced monitoring. The harsh climate is therefore to blame.

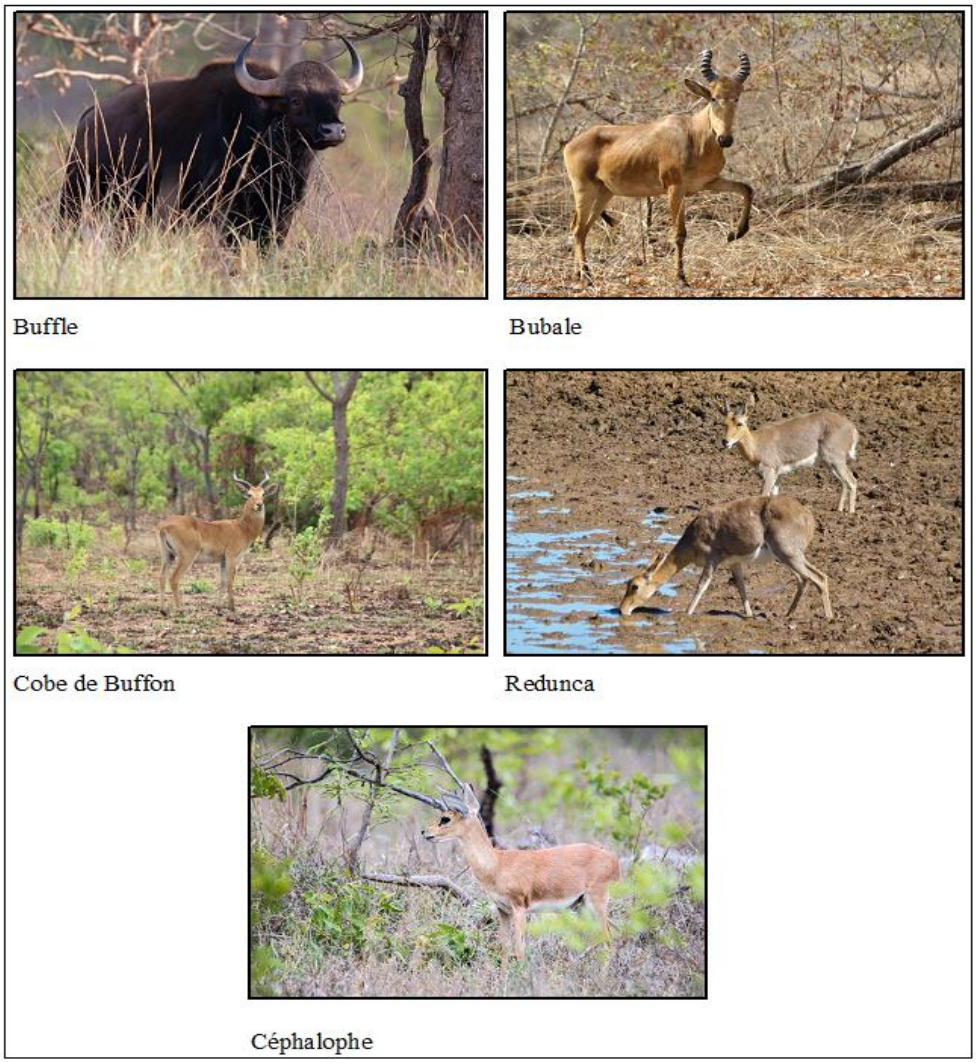


Plate 1: Animal species highly sensitive to harsh climatic conditions in the CNP

Despite the fact that the period is characterised by positive evolution for the animal species of the CNP, the number of these species is decreasing over time. This reduction is partly due to the adverse effects of the climate. In fact, these species need a moderately humid climate to thrive. However, as the park is located in the north of Sudan, the dry season is prolonged and becomes more pronounced with each passing year. The discomfort index in the park, which rose between 1981-1993 and 1994-2020, is also an indicator that should be taken into account when considering the factors behind the losses of these different species.

DISCUSSION

In the Comoé National Park, climate dynamics are reflected in a downward trend in rainfall and an increase in temperature between 1980 and 2020. These results corroborate those of Kouamé (2019, p. 5), who showed that the Comoé National Park in north-eastern Côte d'Ivoire, an area marginalised in terms of rainfall on a national scale, is highly threatened by climate dynamics. According to the author, the area is known for its high temperatures and relatively low rainfall throughout the year. Such a difficult climatic situation is not without consequences for biodiversity. For his part, Kone (2022, p. 50) has highlighted the difficult climatic situation in north-east Côte d'Ivoire between 1960 and 2020, where rainfall is falling while temperatures are rising considerably. The results of our analyses show that the evolution of biodiversity as a whole is experiencing difficulties. Firstly, vegetation cover has been declining over the years as measured by the improved vegetation index (EVI). Estimated at between 0.4 and 0.21 in 2000, it will fluctuate between 0.23 and 0.19 in 2020. In terms of land cover, wooded savannah and forest galleries are declining in favour of grassy savannah and bare soil. These results are in line with the conclusions of the MDDEP study (2011, pp. 2-4), which states that the increase in the concentration of CO_2 in peat bogs results in an increase in the abundance of vascular plants at the expense of mosses. Diomande (2024, pp. 61-67) has also highlighted the impact of temperature, humidity and ultra-violet light on plant and animal species in Côte d'Ivoire. Similarly, the risk of extinction of species and sub-species in particular is rising sharply. This makes them more vulnerable to harsh climatic conditions (Bazairi et al., 2010, p. 13). Despite reinforced protection measures against human activities in the park, animal populations are declining. In fact, certain animal species with increased humidity, rainfall and water requirements are constantly migrating through the park on a seasonal basis. Worse still, certain animal species that are more sensitive to the climate are becoming rarer. This situation has already been mentioned by MDDEP (2011, pp. 3-4), which stated that the reduction in water levels in rivers following droughts has an impact on the aquatic organisms that live in this habitat. Hence the rigid link between the dynamics of climatic factors and the evolution of plant and wildlife species in Comoé National Park.

CONCLUSION

The Comoé National Park is subject to climatic disturbances in the same way as the rest of the world. But it is located in the Sudanian zone in the north-east of Côte d'Ivoire, where climatic conditions are the most difficult in the country. The irregularities of the local climate are reflected in a downward trend in rainfall and constantly rising temperatures. This situation is keeping pace with the difficult evolution of plant and animal species in the park. In fact, the seasonal evolution of the improved vegetation index or EVI fluctuates between floral exuberance at the height of the rainy season and atrophy during the difficult season. On a multiannual scale, the values of the index are in constant decline between 2000, when it was evaluated at between 0.4 and 0.31, and 2020, where it now fluctuates between 0.23 and 0.19. As for wildlife species, despite reinforced protection measures against anthropisation, those most vulnerable to climatic conditions are constantly migrating seasonally to take advantage of milder climatic conditions. Worse still, some of the most sensitive animal species see their populations decline from year to year. This situation demonstrates the rigid link between climate dynamics and changes in biodiversity in the Comoé National Park.

REFERENCES

Diomande, B. I. (2024). Impact de la péjoration climatique sur la biodiversité. *Le Changement climatique en Côte d'Ivoire*. Génésis publishing. ISBN: 979-8-689248-168-7.

Kouamé, K. D. (2019). Jaunissement Mortel du Cocotier et Mutations Sociales à Grand-Lahou, Côte d'Ivoire. *European Scientific Journal*, *15*(25), 130-142.

Ministère du Développement Durables de l'Environnement et des Parcs [MDDEP]. (2011). Impacts des changements climatiques sur la biodiversité du QUÉBEC, pp. 2-4.

Nick, L. (2015). *Gestion durable de la faune et des ressources cynégétiques en Côte d'Ivoire*. Report for the Etats généraux de la forêt, de la faune et des ressources en eau, p. 40.

OIPR. (2015). Plan d'aménagement et de gestion du Parc national de la Comoé pour la période 2015-2024, pp. 14-15.

OIPR. (2015). Plan d'aménagement et de gestion du parc national de la Comoé (Site du Patrimoine mondial et d'une Réserve de biosphère), pp. 34-36.

OIPR. (2015-2024). Plan d'aménagement et de gestion du parc national de la Comoé, pp. 30-33.

OIPR-DZNE. (2017). Rapport de mission de suivi réactif conjointe UNESCO/UICN dans le parc national de la Comoé république de Côte d'Ivoire 3-12 avril 2017, pp. 18-19.

PARC-CI-OIPR. (Mars 2008). Programme cadre de gestion des aires protégées, Etude d'impact environnemental et social, pp. 23-29.