WEST AFRICA BIODIVERSITY AND CLIMATE CHANGE (WA BICC)

CLIMATE CHANGE VULNERABILITY ASSESSMENT REPORT OF THE FRESCO LAGOON LANDSCAPE, CÔTE D'IVOIRE

AUGUST, 2018

This publication was produced for the United States Agency for International Development by Tetra Tech, through a Task Order under the Restoring the Environment through Prosperity, Livelihoods, and Conserving Ecosystems (REPLACE) Indefinite Quantity Contract (USAID Contract No. AID-OAA-I-13-00058, Order Number AID-624-TO-15-00002).

This report was prepared by:
Tetra Tech
159 Bank Street, Suite 300
Burlington, Vermont 05401 USA
Telephone: (802) 495-0282
Fax: (802) 658-4247
Email: international.development@tetratech.com

Tetra Tech Contacts:
Stephen Kelleher, Chief of Party (Stephen.Kelleher@tetratech.com)
Vaneska Litz, Project Manager (Vaneska.Litz@tetratech.com)
Ed Harvey, Deputy Project Manager (Ed.Harvey@tetratech.com)

Citation: Tetra Tech. (2018). USAID/West Africa Biodiversity and Climate Change (WA BiCC), *Report on Climate Change Vulnerability Assessment of the Fresco Lagoon Landscape, Cote D'Ivoire,* 2nd Labone Link, North Labone, Accra, Ghana.

Cover Page Photo: Boats docked with three fishermen on the Fresco lagoon.
(Credit: David Aduama, WA BiCC)

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The WABiCC project (West Africa Biodiversity and Climate Change, *Biodiversité et Changement Climatique en Afrique de l'Ouest*, in French) wishes to express its deepest gratitude to the following individuals and institutions for their relentless support throughout the process of this publication:

(i) At the local level: The Office of the Mayor and Prefecture of Fresco, traditional leaders, heads of various decentralized state agencies and the local populations;

ii) At the national level, the Ministry of Health, the Ministry of Environment and Sustainable Development and the Ministry of Water and Forests Resources.

We equally thank the United Nations University – Institute for Natural Resources in Africa UNU-INRA) and the drafting committee (members listed below) for the vulnerability analysis on climate change in the Fresco lagoon landscape:

- Research Manager, **Prof. Elias T. Ayuk**;
- Team Leader, **Prof. Jacques-André Ndione**;
- Climate Change Analyst, **Dr Dje Bernard Kouakou**;
- Institutional Strengthening Specialists, **Prof. Binate Namizata** and **Mr. Jonathan Beugré Ngessan;**
- Livelihood and Value Chain Specialist, **Dr Godfred Jasaw**;
- Outreach Specialist, **Mrs. Praise Nutakor**;
- Environmental Policy Research Fellow, **Dr Ngozi Finette Stewart-Unuigbe**;
- Mangrove Ecologist and Forester, **Prof. Wadja Egnankou Mathieu**;
- Water Resources Specialist, **Dr Vamoryba Fadika**; and
- GIS Specialist, **Mr. Kwabena Asubonteng**.

ACRONYMS AND ABREVIATIONS

AISH/IAHS	International Association of Hydrological Sciences
ANADER	National Agency for Rural Development Support
ASECNA	Air Navigation Safety Agency in Africa and Madagascar
CCVA	*Climate change vulnerability assessment*
UNFCCC	United Nations Framework Convention on Climate Change
CMIP	*Coupled Model Intercomparison Project*
GFCS	Global Climate Services Framework
CNRS	National Centre for Scientific Research
DMN	National Meteorology Directorate
REn	Renewable Energy
RET	Real EvaporationTranspiration
FIT	Front Inter Tropical
GHGs	Greenhouse gases
IPCC	Intergovernmental Panel on Climate Change
GR2M	Rural Engineering with 2 parameters Monthly
IRD	Institute of Research for Development
DFM	Digital Field Model
MINSEDD	Ministry of Sanitation, Environment and Sustainable Development
NDP	National Development Program
NCCP	National Climate Change Program
RCP	*Representative Concentration Pathway*
GPHS	General Population and Housing Census
SNLCC	National Strategy to Fight Climate Change
SODEXAM	Société d'Exploitation et de Développement Aéroportuaire, Aéronautique et météorologique
ES	Ecosystem service
SES	Socio-Ecological Systems
TSO	Ocean Surface Temperature
UNU-INRA	*United Nations University - Institute for Natural Resources in Africa*
WABiCC	*West Africa Biodiversity and Climate Change*

1.0 EXECUTIVE SUMMARY

Climate change vulnerability assessment of the Fresco lagoon landscape was carried out using the prism of socio-ecological systems (SES) as the analytical framework. Located in southwestern Côte d'Ivoire, the Fresco lagoon landscape is part of the coastal zone that has experienced a 0.5°C warming over the past 50 years since the late 60s. Fresco has also experienced a downward trend in rainfall since the 80s, an average sea level rise of 19 cm from 1961 to 2010 and an upward trend in flood, dry spell and storm frequencies. This variability is also marked by a 40% decrease in the surface runoff and in the water volumes of the hydrogeological reserves likely to supply them. With regard to climate projections, it is expected that the average temperatures in the Fresco region will increase from 1°C in 2050 to 1.5°C in 2100 for the RCP4.5 scenario on the one hand and up to 2°C in 2050 and 4°C in 2100 for the RCP.5 scenario on the other hand. Regarding rainfall, its seasonal decrease is associated with a change in its distribution. Finally, it is to be expected that the frequency and intensity of extreme weather and climate events will increase; as, climate impacts are seriously being felt by communities in their day-to-day activities, essentially in agriculture and fisheries.

Household perception results show that extreme events (sea level rise, severe storms, storm surges, sea surface temperature changes, prolonged droughts and extreme precipitation) are the main indicators of climate change impacts on the Fresco lagoon landscape, depending on the community. Similarly, forests and mangroves are in rapid decline, as most wood species are cut for export and for firewood. The forest ecosystem, including mangroves, is degraded by 60-70% compared to its level in the 90's. This decline is directly related to how communities manage and use ecosystem services. Households identified nine key ecosystem services as essential within their communities. There is significant variation in household use and dependence on these critical ecosystem supply services. Of these services, firewood is the most common. Almost all respondents affirmed that other ecosystem services (non supply services), including for instance soil fertility, aesthetic value etc., were in degrading conditions. The results also indicate strong population growth, associated with overfishing, which is highly destructive, and unsustainable harvesting of ecosystem products as well as changes in land use as the main drivers of change and challenges to the sustainability of ecosystems in the Fresco lagoon landscape. From an institutional point of view, the analysis reveals: (i) the absence or weak implementation of national policies at the local level; (ii) the existence of a multitude of institutions, which unfortunately are poorly or little informed about climate change issues and their implications (direct or indirect) on the way of life of local populations; (iii) the non-integration of climate change adaptation into local development policies.

In light of all these, the social, physical, natural and financial assets of households were considered weak in the region. Moreover, the vulnerability index shows that zone 1 (which covers the first 10 kilometres around Fresco), encompassing the Fresco lagoon, remains the most vulnerable zone with regard to the occurrence of climate hazards, the pressure on resources and the responses to disasters. As a matter of fact, this zone is credited with a value of 5/5. Zone 2 (which concerns the stretch between 11 and 20 kilometres north of Fresco) and zone 3 (which concerns the area beyond 20 kilometres) are credited with 4/5 on the vulnerability scale.

Adaptation options to support sustainable alternative livelihoods, maintain ecosystem resilience and improve community resilience were identified. These options include: forest restoration, including mangrove forests, improved extension services, input support programs, strengthening food and fish processing and storage infrastructure, and reducing resource consumption using simple but high potential energy efficiency technologies for households and women fish processors. In light with the above, adaptive capacity would be better strengthened by facilitating institutional linkages and coordinating responses at several levels on the one hand and across all borders of local institutions on the other. Thus, the integration of climate change adaptation into communal development plan is a necessity if a more sustainable, and transformational, adaptation process is to be achieved.

2.0 INTRODUCTION

Today, there is no doubt about the awareness of the problem of climate change in developing countries. Even if there is still room for progress, both for knowledge production and for its availability, as well as for the ability to implement knowledge and policies. In order to reverse the current trend, efforts are being made to take better account of these changes with regard to their serious economic implications to the entire development process and to the daily lives of our populations. Climate information plays an important role in the design, development and sustainability of a wide range of activities in many socio-economic sectors, such as agriculture, energy and water resource management, transport, tourism and infrastructure development. The challenge of climate risk is considerable in a community like Fresco, given the environmental, economic and social impacts that directly affect the quality of life of residents and natural resources as well as their preservation. The consequences of climate change within the Fresco region are multiple. Indeed, fishing, tourism, agriculture, natural risks, biodiversity, etc. are all sectors that are already seriously and negatively affected. However, in order to properly anticipate and adapt to potential climate change impacts, it is necessary to, fist and foremost, analyze both current and future climate trends.

In order to respond to crucial climate change problems, Côte d'Ivoire has developed many strategies and interventions in recent years. One of these strategies is "*The Climate change adaptation action plan for coastal areas in Côte d'Ivoire*". However, the country's interventions in coastal areas pay much attention to coastal erosion, and very little has been done to integrate anthropogenic and climate analysis to properly diagnose and propose solutions to the problems posed by climate change. In recent years, effects of climate change have been more pronounced, with extreme weather and tidal conditions already causing significant damage in some coastal areas of the country. In addition, exploratory studies conducted by the West Africa Biodiversity and Climate Change (WABiCC) program indicate that climate change effects are already being felt in the Fresco coastal ecosystem complex, thereby increasing the region's vulnerability. It is likely that the interlinkages between climate change and human-induced changes, such as mangrove deforestation and forest and watershed degradation, could have profound implications for the socio-economic development of the region, including local livelihood strategies. Already, the overexploitation of natural resources around the catchment area certainly does not only have dire consequenses on the communities, but also puts the West African manatee (Trichechus senegalensis) at serious risk, classified on the list of endangered species (Akoi 2004), hence worsening the impacts of climate change and the vulnerability of the Fresco lagoon. In addition, population growth in the catchment area may also have led to competition between users and, as a result, the depletion of resources and the destruction of mangroves.

These ideas illustrate the complex range of physical, environmental, social, economic, legislative/regulatory and political factors that determine people's vulnerability to climate change. For adaptation efforts to be successful, vulnerability assessment must go beyond identifying the vulnerable landscape. Vulnerability assessment, analysis and adaptation planning processes should involve all relevant national and local institutions and interest groups, including local communities and in particular the most vulnerable members of these communities such as women, youth and migrants. These processes should examine the social, economic and political factors of vulnerability in order to identify the most vulnerable people in the communities and ensure that their needs, priorities and aspirations are covered in the assessment. This allows policy makers and adaptation practitioners to better target resources and tailor interventions where they are mostly needed.

At any scale, assessing climate change vulnerability and then developing adaptation measures requires high-quality information such as climate data (temperature, precipitation for both climate variability and projections, and especially the frequency of extreme events, etc.) and non-climatie information, such as the current situation on the ground for different sectors including ecosystem services, water resources, agriculture and food security, human health, biodiversity and coastal areas.

However, experience has shown that climate change vulnerability differs within and between countries, villages, communities and even households. Current approaches to vulnerability assessment for the allocation of adaptation funds do not always take into account these inherent differences (PECCN, 2011). To ensure that appropriate adaptation practices reach out to the most vulnerable people, assessment, analysis and planning processes that capture these differences and provide information on the most vulnerable areas, communities, people and resources in an accurate manner (quantification) are needed. Additionally, in terms of understanding how best to conduct climate change adaptation strategies, even if tangible evidence has been acquired over the years, the fact remains that we are still in the early stages... The availability of long-term climate data is limited for many landscapes in Africa. In addition, the collection of socio-economic data in terms of time is generally not subject to a certain regularity and a well-developed policy, but rather to specific interventions depending on projects and programs, not to mention the authenticity of the data. Taking all these constraints into account, the WABiCC program collected detailed information on current and future climate change impacts on ecological and socio-economic systems in Fresco, Côte d'Ivoire.

This information, after analysis, will be used to determine the most effective adaptation options to increase the resilience of ecosystems and communities to climate change and to guide future WABiCC program activities and national policies in the Fresco landscape area.

2.1 OBJECTIVES

The specific objectives of the climate change vulnerability assessment of the Fresco lagoon landscape (*CCVA*[1]) are :

1. document and understand the climate variability and climate projections expected to impact the landscape of the Fresco Lagoon and its catchment areas;
2. assess how these meteorological and climate phenomena, combined with anthropogenic factors, can affect the livelihoods and ecosystem services of the Fresco Lagoon and its surrounding landscape;
3. co-identify existing and potential adaptive responses that can be implemented to improve the resilience of local communities and ecosystems to climate-related impacts.

This vulnerability assessment report of the Fresco lagoon catchment area is structured in six (6) sections that respectively present the methodological approach, the exposure that deals with climate analysis (variability and projections), the sensitivity of communities and ecosystems, the adaptive capacity of national institutions and systems, a synoptic view of vulnerability and recommendations on adaptation strategies. Finally, this report is the result of six (6) thematic reports that in turn examined: (1) climate assessment, (2) water resources assessment, (3) mangrove analysis, (4) land use and occupancy analysis, (5) ecosystem and livelihood analysis and (6) institutional vulnerability analysis.

[1]- CCVA: *Climate change vulnerability assesssment* ; en français (EVCC) : Evaluation de la vulnérabilité aux changements climatiques

3.0 METHODOLOGICAL APPROACH

3.1 STUDY SITE

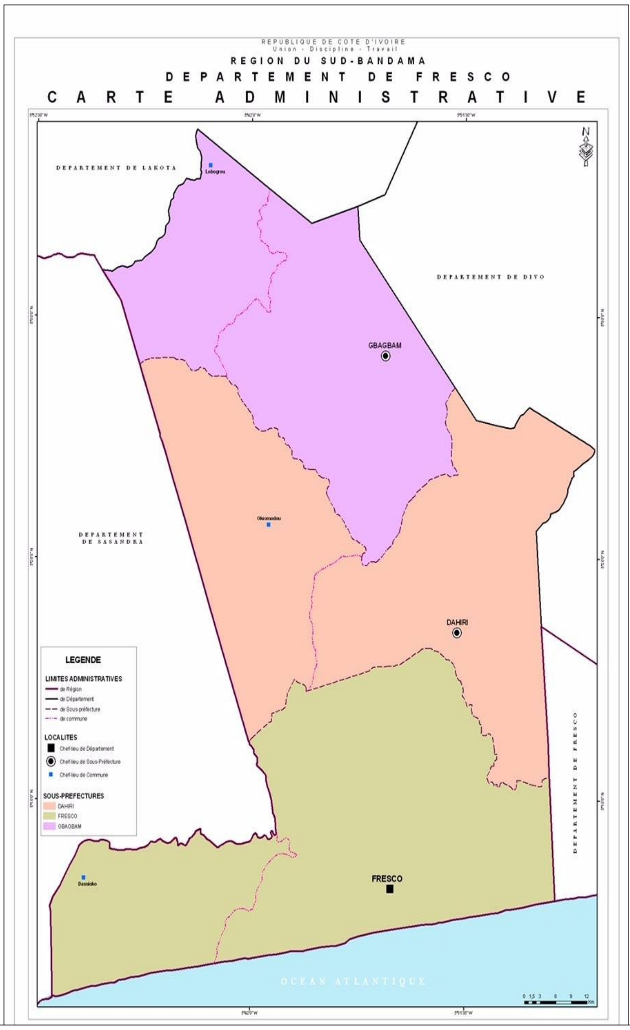
This climate change vulnerability assessment is conducted in the Fresco lagoon landscape (Figure 1) and was carried out between February and March 2018. As a matter of fact, according to Egnankou et al (2004), the Fresco area or locally called Koyiri is located in the southern Bandama administrative region (about 11,000 km²), extends between 5°03' and 5°11' north latitude and between 5°29' and 5°44' west longitude. It is located 225 km west of Abidjan and the nearest town is Grand-Lahou, 80 km away.

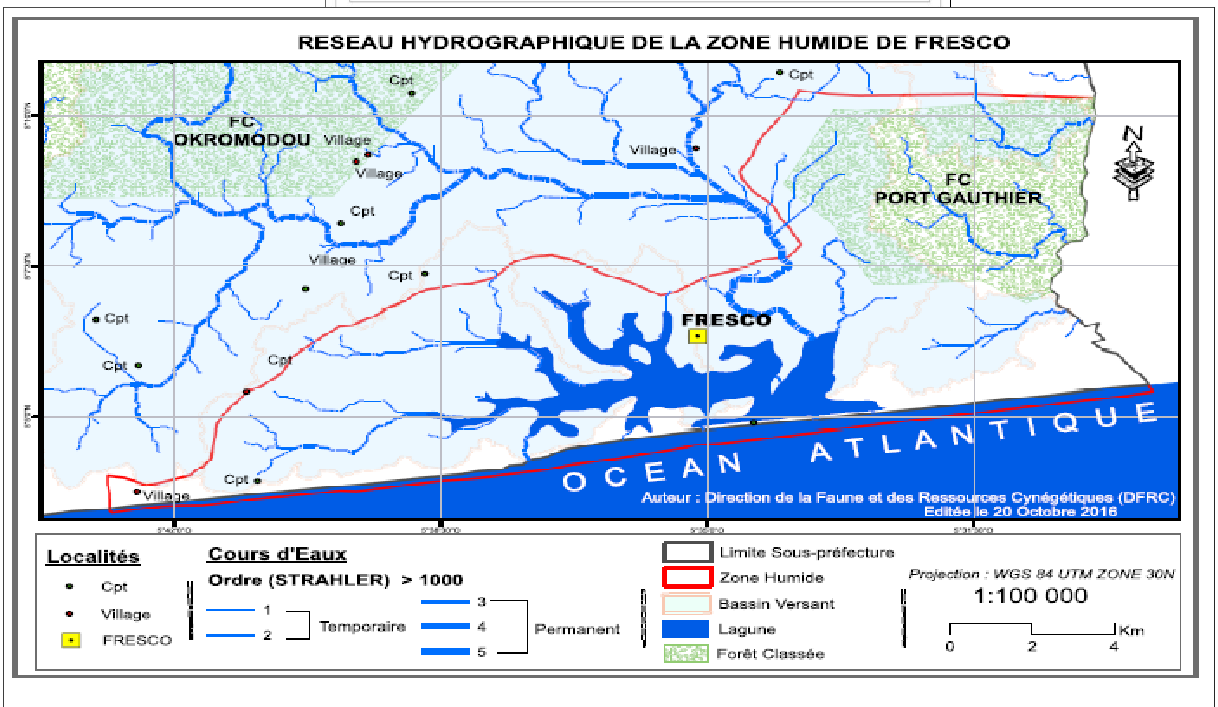
The definition of the study site took into account the interactions between terrestrial ecosystems (dry land forests), the rivers that flow into the lagoon including their bassins and estuarine mangroves, the lagoon with its mangroves and its inlet to the ocean. This approach is in line with the principles of the Abidjan Convention Protocol, which takes special account of:

- the biological richness, dynamics and natural functioning of the intertidal zone as well as the complementarity and interdependency between the marine and land parts forming a single entity;
- the integration of all elements relating to hydrological, geomorphological, climate, ecological, socio-economic and cultural systems in order not to exceed the carrying capacity of the coastal zone and to prevent the negative effects of natural disasters.

At Fresco, there are real lively cliffs, compressed by the sea. The western coast is a forest area where agro-industrial plantations (palm and rubber plantations) have spread over the past 20 years (Sankaré et Aka, 2016). We note that the Fresco lagoon stretches from east to west, over a length of about 6 km, a width of between 2 and 4 km with an average depth of 4 m. It covers an area ranging from 17 km² during the dry season to 29 km² at the peak of the rainy season. It receives waters of the Bolo and Niouniourou rivers, and joints the sea through the non-permanent Fresco inlet channel. According to Issola et al (2008), an examination of the bathymetric map of the Fresco lagoon shows that depths range from 0 to 3.5 m. Over 17 km² of the total area of the Fresco lagoon, the depths do not exceed 1.8 m, especially in the vicinity of the island; the highest depths are observed at the outlet of the Bolo River, where they reach 3.5 m. Two lagoon depressions are clearly identifiable to the east, at the outlet of the Bolo. This is the main depression 3.2 m deep, southeast of the lagoon. It is located near the sandbank between the lagoon and the Atlantic Ocean and a little further north, a maximum of 2.8 m deep depression, not far from the Bolo River.

Figure 1: Location of the study site (above is the administration map of the Fresco region; below is the view of the Fresco lagoon)

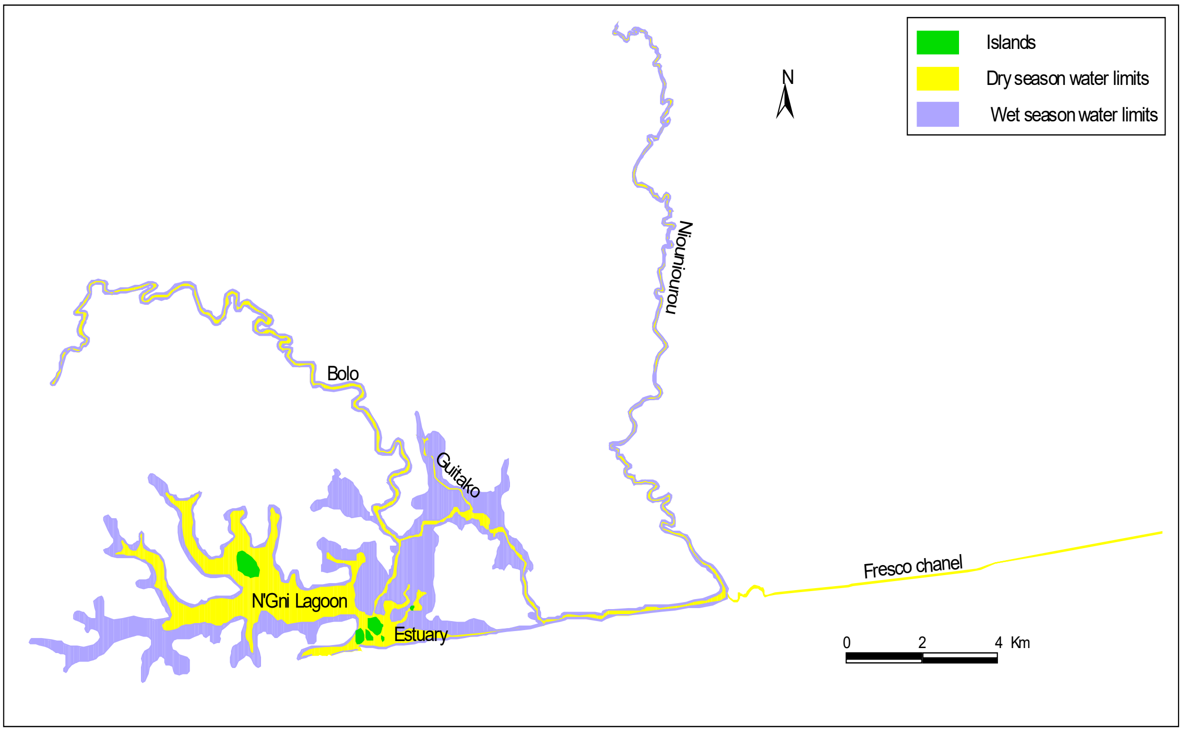




3.1.1 HYDROLOGY

Surface waters consist of rivers and the lagoon that leads to the Atlantic Ocean (Figure 2). The Niouniourou River has a basin of 1791 km^2 and takes its source from the west of the city of Divo and flows south. This river collects the Diogoro River from the left and flows through an inland waterway before reaching the sea. This waterbody is gauged in Dahiri. The Bolo River flows from the Okromodou forest reserve and flows into the Gogbey lagoon near the town of Fresco. The Krokro River is the main tributary. This river is not yet gauged. The Fresco lagoon is the smallest and shallowest in the lagoon system of Cote d'Ivoire. It is fed by a low-flow river (the Bolo) in its eastern part. The slow flow of this river makes the opening of its mouth uncertain. Moreover, during periods of high to lower lagoon floods, fishermen open the channel themselves by excavating the beach barrier. Indeed, fishes, which take refuge in the mangroves, return to the open water when the water recedes and thus become accessible to fishermen. The Gogbey lagoon links with the Grand-Lahou lagoon via a canal that has been inaccessible for some years now due to lack of maintenance.

Figure 2: hydrographic network of Fresco



Fresco's groundwater resources are captured by ONEP-operated drilling, boreholes and wells 47, 26 and 8 respectively, with flows ranging from 0.2 to 21.4 m^3/h.

The work on physical and chemical parameters carried out by Issola et al (2008) can be summarized as follows: the average annual surface water temperature of the Fresco lagoon of 28.47°C ranges from 27.90°C to 28.96°C. The lowest temperatures are observed in the deltaic zone with annual averages of 27.90°C and 27.95°C. The annual average salinity of surface waters of the Fresco lagoon is about 15.69 mg/l with minimum and maximum average values of 12.48 mg/l and 18.05 mg/l respectively. The lowest salinities are observed in the delta area with annual averages of 12.48 mg/l and 14.09 mg/l. Salinity is more pronounced during the dry seasons and the high rainy season. It is lower during the short rainy season. In the Central and Western zones, salinity is high during the dry season and the short rainy season. The lowest values are observed during the high rainy season. The average annual dissolved oxygen concentration in the surface waters of the Fresco Lagoon is 5.16 mg/l and ranges from 4.66 mg/l to 5.50 mg/l. The distribution of dissolved oxygen concentration is quite homogeneous. However, it is noted that the lowest concentrations are obtained in the central and western parts of the lagoon during the dry season, in the delta area during the rainy season, and almost everywhere during the rainy season (Sankaré and Aka, 2016).

3.1.2 FAUNA AND FLORA

Upland forests, swampy grasslands and riparian forests include plant species, some of which are endangered. In this part of the country, there are three forest reserves. These are the Okromodro, Dassioko and Port Gauthier forest reserves. The Port Gauthier forest reserve is a swampy forest, an edaphic formation of fresh water that has developed in the poorly drained lowlands with permanent hydromorphs located to the east between the Bolo and Niouniourou rivers. Despite its protected status and difficult access, this forest, which is very important for the local population for its many services, is severely degraded. Ethnobotanical work by Soro et al (2004), cited by Egnankou (2018), identified 20 plant species with multiple traditional uses from 16 genera and 10 families collected from the swamp forest. Harvested organs and plants are used in the fields of pharmacopoeia (11 species), food (7 species), handicrafts (5 species), house building (5 species) and other fields (8 species). Organ and plant harvesting is higher in both dry seasons all year round. The different species used are listed in table 1.

Three plant species numerically dominate mangrove stands. These are Rhizophora racemosa (RHIZOPHORACEAE), Avicennia germinans (AVICENNIACEAE) and Paspalum vaginatum grass. They are associated with companion species such as Hibiscus tiliaceus (MALVACEAE), Drepanocarpus lunatus (PAPILIONACEAE), Dalbergia ecastaphyllum (PAPILIONACEAE) and Acrostichum aureum (ADIANTACEAE).

Like other lagoons in the country, the Fresco lagoon and mangroves are home to many plant and animal species other than mangroves and their companion species. Thus, according to Sankaré and Aka (2016), there are five categories of phytoplankton: Cyanophyceae, Diatomophyceae, Pyrrhophyceae, Chlorophyceae and Euglenophyceae. At the Microphytobenthos level, there are also five classes: Phylloflagates, Mobile Cyanophyceae, Sedentary Cyanophyceae, Free Diatoms, Sedentary Diatoms. In addition, a relatively large number of endemic plants (West African and Ivoirian endemics) reside in the Fresco Wetland: Cissus touraensis (VITACEAE), Albertisinia mangenotii (MENISPERMACEAE), Mapania ivorensis (CYPERACEAE), etc. Mangrove fauna is described in the next chapter (Sankaré and Aka, 2016).

In addition to the traditional ecosystem services provided by mangroves in general (habitat, refuge, breeding area, spawning ground, feeding ground, local climate, water exchange between lagoon and sea, sediment capture and management, benchmark area, etc.), the Fresco wetland and mangroves constitute a buffer receptacle for surface fresh water of continental origin and ground brackish water. As a result, they play an important role in the hydrological cycle of the region by contributing to the maintenance of water balance, nesting, hosting and transit sites for many migratory bird species including Pandion heliaetus (Osprey), Egretta garzetta (Little Egret), Phalacrocorax africanus (African cormorant), Nycticorax nycticorax (grey night heron), Butiroides striatus (green heron), Ardea purpurea (purple heron), Ardea cinerea (grey heron), Circus aeruginosus (reed harrier), Tringa ochropus (white knight), Actilis hypoleucos (guinette knight), etc.

It is also a transit area for many resident or partially resident bird species, including the kingfisher (Ceryle rudis), the Senegalese coucal (Centropus senegalensis), the beef heron (Bulbucus ibis), the Tchagra telephone (Tchagra senegala), etc. and spawning grounds for marine turtle species: Dermochelys coriacea (Leatherback turtle); Lepidochelys olivacea (Olive turtle), Chelonia mydas (Green turtle), Caretta caretta (Caretta turtle), Testudo sulcata (Savanna turtle), Trionyx triungus (Freshwater turtle).

The Fresco wetland and mangroves, which have been designated as Ramsar sites since 2004, are home to many species of fauna and flora, some of which are endangered and others are vulnerable due to human pressures on them and their habitats. These endangered species (CITES and CMS Appendix 1), fully protected by national legislation are: the peregrine falcon (Falco peregrinus), the forest elephant (Loxodonta africana cyclotis); the chimpanzee (Pan troglodytes); the cercopithecus diane (Cercopithecus diana), etc.

In the mangrove ecosystem, mangroves have certain characteristic that, through their morphological structure and functioning, play an important role in the life cycle of estuarine fauna. Of the six (6) mangrove species found in West Africa, only three (3) are found in Côte d'Ivoire: Rhizophora racemosa or red mangrove, Avicennia germinans or white mangrove and Conocarpus erectus or grey mangrove. The grey mangrove Conocarpus erectus is an endangered species in Côte d'Ivoire. Mangroves themselves, ecosystems of biological importance, are currently endangered and are at threat of deforestation due to the many stresses they are subjected to (Egnankou and Sankaré 2004). In addition to mangroves species, there are many other plant species that tolerate brackish substrates, but also grow on unsalted substrates or on shoreline. Among these species are Dalbergia ecastaphyllum, Drepanocarpus lunatus, Hibiscus lunatus, Acrostichum aureum, Phoenix reclinata and Pandanus candelabrum.

A total of 56 plant species have been recorded in mangroves and other wetlands of the Fresco lagoon landscape, as presented in table 2.

Reputed for its flora, the Fresco lagoon landscape is equally well known for its fauna. Indeed, it contains many animal species, some of which are rare and/or endangered. Among these species, we can mention:

- endangered species: forest elephant, crocodile, pygmy hippopotamus (Choeropsis liberiensis) and Chimpanzee;
- vulnerable species: the manatee (Trichechus senegalensis); migratory turtles (Dermochelys coriacea, Lepidochelys olivacea and Chelona mydas).

There are many other non-infeodated mammals that regularly frequent mangroves at Rhizophora racemose, as well as several primates species (Pan troglodytes, Cercopithecus petaurista, C. mona, etc.), as indicated included in the summary presentation of the Fresco fauna; tableau 3,

Avian fauna includes several waterbird species, some of which have a special status (rare, endangered, endemic, etc.). table 4 shows some birds observed in the Fresco area (Nicole et al, 1987).

In this part of the country, as in all Ivorian coastal ecosystems, the biodiversity of the Fresco lagoon landscape is constantly declining due to poor method of resource exploitation occasioned by uncontrolled land clearing for farming purposes. For example, the level of mangrove destruction around the lagoon complex, which was between 20 and 50% in 1985, can be estimated at 60%, and even 80% today. The construction of the coastal road, which did not rigorously comply with the recommendations of the environmental impact assessment is an infrastructure that is favorable to the development of this region, nevertheless remains a means of accelerating human pressure. The disastrous state of the Dassioko and Part-Gauthier forest reserves, for example, attests to this fact. However, these forests were initially home to exceptional biological diversity. Several endangered species of Ivorian flora have been identified. Among the fauna, there are also species with a special status such as the dwarf hippopotamus, the African elephant, reptiles and various bird species. The aquatic environment is particularly rich in manatees.

3.1.3 CLIMATE

Hughes and Hughes (1992) indicate that the climate of the Fresco region, generally hot and humid, is a transition from the equatorial to the tropical.

The country generally experiences significant temperature variations between North and South, but also throughout the year depending on the season. Temperatures fluctuate around 28°C on average.

Two major climate zones coexist: the equatorial climate and the tropical savannah climate, itself more or less dry. The southern part of the country, including the Fresco region, is subject to a sub-equatorial climate (Attiéen or Akiéen) with an average annual temperature of 25°C to 33.0°C, rainfall of 1400 to 2500 mm/year, a humidity rate of around 80 to 90% over the year and two rainy seasons interrupted by two dry seasons of unequal duration.

3.1.4 HUMAN SETTLEMENTS AND SOCIO-ECONOMIC ACTIVITIES

A total of twenty-two (22) human settlements have been recorded in the Fresco region. These settlements are distributed as follows: 12 for the Fresco sub-prefecture, 4 for the Dahiri sub-prefecture and 6 for the Gbagbam sub-prefecture. The Fresco population is summarized in Table 5. It is estimated at 101,298 inhabitants for the entire region, including 53,579 men and 47,719 women for a male (MR) ratio of 112.3 per cent.

Table 5: Population distribution of the Fresco region by sub-prefecture and localities by gender in 2014

RGPH 2014	Homme	Femme	Total	RM (%)
COUNTY TOTAL	**53 579**	**47 719**	**101 298**	**112.3**
SP DAHIRI				
TOTAL SOUS-PREFECTURE	**19 011**	**17 580**	**36 591**	**108.1**
NAME OF LOCALITIES				
TOTAL NON SETTLEMENT AREA	19 011	17 580	7 140	108.1
DAHIRI	4 270	4 127	1 150	103.5
GOMÉNÉBÉRI	5 307	4 824	4 765	110.0
OKROMODOU	6 834	6 220	672	109.9
ZÉRIBÉRI	2 600	2 409	553	107.9
SP GBAGBAM				
TOTAL SOUS-PREFECTURE	**12 646**	**11 003**	**23 649**	**114.93**
NAME OF LOCALITIES				
NON SETTLEMENT AREA	12 646	11 003	23 649	114.9
DIGBODOU	226	323	549	70.0
GABILILIÉ	1 199	721	1 920	166.3
GBAGBAM	7 142	6 512	13 654	109.7
GROGBALEDOU	1 861	1 662	3 523	112.0
KROUKROU	1 545	1 373	2 918	112.5
ZAKPABERI	673	412	1 085	163.3
SP FRESCO				
TOTAL SOUS-PREFECTURE	**21 922**	**19 136**	**41 058**	**114.6**
NAME OF LOCALITIES				
TOTAL NON SETTLEMENT AREA	12 881	10 794	23 675	119.3
BOHICO	108	95	203	113.7
FRESCO	4 676	3 857	8 533	121.2
ZAKARÉKO	2 337	1 923	4 260	121.5
ZÉGBAN 1	3 436	2 965	6 401	115.9
ZÉGBAN 2	2 324	1 954	4 278	118.9
TOTAL NON SETTLEMENT AREA	9 041	8 342	17 383	108.4
BOLOROUKO	1 627	1 420	3 047	114.6
DASSIOKO	2 386	2 267	4 653	105.2
KOSSO	2 794	2 519	5 313	110.9
ZUZUOKO	2 234	2 136	4 370	104.6

Source: Sankaré et Aka (2016)

The Godiés are the ethnic group in the region. The population of Fresco is growing rapidly due to the continuous immigration of people across the West African Sub-Region and the resettlement of Ivorians in forest areas. Thus the population of Fresco has increased from about 16,000 inhabitants in 1998 to 20,000 inhabitants during the last decade. The population is composed of the Godié ethnic group, native to the region, the Akan, the Mande, the Gours or voltaic, the Krou. We also noted the prominent presence of Burkinabés followed by the Lebanese, Ghanaians, Togolese, Beninese and Guineans. Christianity, Islam, animism are the main religious colours.

Unlike the marine environment, lagoon fishing communities include both nationals and foreigners. There are few lagoon villages, as the Godié and Neho villages are on the mainland. People tend to assert their authority over the waters as owners of the lagoon area, which is considered an extension of their land. In the landscape of the Fresco lagoon, this appropriation is so deeply rooted in morals that the lagoon is compartmentalized. Entire portions belong to families who organize fishing activities (installation of fishermen and collection of fees). The local populations are convinced that their historic settlement on the shores of the lagoon gives them a certain legitimacy and title to the lagoon as well as portions of land along the lagoon (Sankaré and Aka, 2016).

In contrast to the lagoon community, there is the maritime community. Indeed, located on the edge of the Gbôklê lagoon, the Fresco township depends on artisanal fishing both at sea and in the lagoon. Sea fishing is carried out by the Fantis, non-indigenous population, who came from Ghana in the 1920s. Godié and Fanti lived on the same site until 1966. **In view of the advance of coastal erosion due to sea level rise, the Godié have opted for another location (their current settlement). This historical shift is the first sign of adaptation to climate change. This means that the manifestations of climate change in Fresco are not new; they date more than fifty years back.**

The Fantis' way of life and work is essentially communitarian - that is, community members share the same values and social norms. Hence, the unity of language and culture serves as the foundation for the expression of solidarity, fraternity and the strengthening of group cohesion in the host community. Intra-Community links are very strong (existence of mutual aid associations). Crews of fishing units (collective fishing) are recruited in the villages of origin on family basis or on a commitment legitimized by the community in order to preserve the cohesion of the group. In return, payment of the crew is also made to the village at the end of the contract. The wives of the fishermen who are members of the fishing unit play an important role downstream, particularly in smoking and marketing fishery products. Artisanal marine catches are sold in the Sassandra and San-Pedro markets because customers buy them at higher prices (Sankaré and Aka, 2016). With regard to socio-economic activities, table 6 provides a brief overview of the situation and types of socio-economic activities in the Fresco region.

Agriculture, fisheries and trade remain the main socio-economic activities of the region (Sankaré and Aka, 2016). Undeniably, for agriculture, a distinction must be made between cash crops on the one hand and food crops on the other. The Fresco region depends on cocoa, coffee, oil palm and rubber plantation activities; it is a centre for gathering dried cocoa beans from the hinterland and transported to the country's two major ports: the Port of Abidjan and the San Pedro port.

Cocoa production is sharply down due to swalen shoot disease, reduced rainfall, land conflicts, the spread of rubber plantation, and changing weather conditions (wet season from July to September). The agricultural services are no longer able to produce statistics on the various products due to lack of harmonization of data between ANADER and the Coffee-Cocoa Council. However, rainfall is a factor to consider in explaining the reduction in production. Rainfall, although has become a limiting factor, does not reduce the attention paid to rubber growing, which consumes a lot of space; it occupies the lowlands which should have served as lands for growing food crops.

With regard to food crops, we note with Sankaré and Aka (2016) that in the Fresco forest area, rural populations grow cassava (a basic crop for the production of attiéké), plantain, rice, corn, pepper, okra, etc. These products are sold locally and in other cities across the country. Some cooperatives exist and are very active in processing, some of which are: " *lumière EKLOHEWOU*" group and the United Sisters' Association (*Association des sœurs unies*.) Women are interested in this food crop processing sector, but funding is still a challenge.

The lagoon fishery records low catches in general (about 300 tons per year; Sankaré and Aka, 2016) compared to catches in other lagoons in the country. Fish catches are made with hawks, various traps and they are also low and are dominated by Tilapias and the African sea catfish. Lagoon catches are found on the local market. The local populations are not fishermen, but some people engage in fishing just for their own consumption. However, the hunting of walking crabs in swampy areas is key. As a matter of fact, most young people in the Fresco township hunt walking crabs and sell them to women to make ends meet. Walking crab catches used to be plentiful, but have been declining recently, mainly due to overexploitation (Sankaré and Aka, 2016).

Still on the issue of lagoon, it should be noted that the Fantis are authorized to fish there for 3 days after each reopening of the inlet, which is constantly obstructed. They constitute an important workforce with techniques related to the act. Otherwise, fishing in the lagoon is the sole responsibility of local fishermen. The fisherfolks use traps, scales, fixed nets for crustaceans (swimming crabs, pink shrimps, freshwater shrimps), sparrowhawks.). However, the preservation of this fascinating aquatic diversity is necessary (Biological Conservation Report, 2008, cited by Sankaré and Aka, 2016). This lagoon is no longer protected and is silting up due to the permanent non-opening of the inlet, but also due to solid inputs due to the cutting down of vegetation and deforestation in the upstream of the catchment area. When the inlet is closed, it poses a crucial problem for lagoon fishing; in addition to silting and sedimentation, there are problems related to water quality and even eutrophication of the lagoon, which has its share of impacts on both mangroves and fish. Let us remember that the site of marine fishermen is threatened by both the sea and the lagoon during high tide and high water periods respectively.

Sea fishing is practiced by the Fantis, but with other types of gear (beach seines, rotating scenes, etc.). They catch several species of fish (mules, herring, rays, soles, sardinella, etc.). Catches are estimated between 900 and 1000 tons per year. Fresh fish is sold daily in the market by the indigenous women of Fresco, the "Kohiri". Sankaré and Aka (2016) inform us that smoked fish is sold on a specific day of the week to ensure enough supply to the market, i. e. Friday. Every woman participates in this market without exception. Fishermen pay royalties to the village of Fresco. This fee amounts to 30,000 CFA francs per month, distributed as follows: 20,000 francs for fishing on the lagoon and 10,000 francs for fishing at sea. A cooperative of women selling fresh fish is set up.

Given the implications of fishing in relation to vegetation cover, there is a particular concern about the future of the latter... Because in this particular context, it goes without saying that mangrove forest and other types of vegetation are under countless pressures to conserve fish and make it conducive to smoke. According to indiscretions, it is the youth of Godié (local ethnic group) who attack these types of vegetation and sell them (tree trunks) to Fanti women. Thus, mangroves are attacked as well as the nearby forest (Sankaré and Aka, 2016).

One would have thought that tourism would occupy a good place in the socio-economic activities in the Fresco lagoon site, but the situation is far from being so. The region has a Ramsar Site (Wetland of International Importance). These various factors are combined with the forest reserved of the port of Gauthier (11,000 ha), lagoon manatees, mangroves with several layers of evolution, spectacular rock outcrops, cliffs and coastal beaches. Walking crabs in the region's wetlands are attractive

This complex is enhanced by the fishermen's village located between the lagoon and the sea, the scree from the cliff at Nomoré which has become a UNESCO World Heritage Site (Landragen, 2015, cited by Sankaré and Aka, 2016). As a coastal city, Fresco, for its development, has not focused on tourism to attract more tourists and international meetings (symposia and seminars).

3.2 EXPLORATORY SURVEY

An exploratory survey was conducted by the WA BiCC program in February 2016. During this survey, various meetings with community members and local institutions were held, and visits to the lagoon, rivers and mangroves were carried out, including an exploratory study of the socio-ecological context conducted by Sankaré and Aka. (2016). The results of this survey concluded that the coastal ecosystems of the lagoon and Fresco communities could be affected by the current and anticipated effects of climate change such as sea level rise, heat waves and increased storms, among others. In addition, the Fresco lagoon has a complex water flow dynamic in which the lagoon and river system, which hosts the largest mangroves in the region, suffers from acute sedimentation due to recurrent unstable opening and closing between the lagoon and the coast sometimes throughout the year. This dynamic adds to Fresco's lagoon vulnerability, exacerbated by various human activities upstream and downstream, of which agriculture and fishing seem to be on top. The results also revealed that mangroves could be important for coastal resilience to the impacts of climate change in this region. Therefore, these results guided the focus of this study on communities and their relationship to mangroves. However, given the implications of upstream activities in the dynamics of the Fresco lagoon (mangrove health, livelihoods and lagoon sedimentation), the geographical area studied was extended to the entire Fresco Ramsar Site and its surroundings

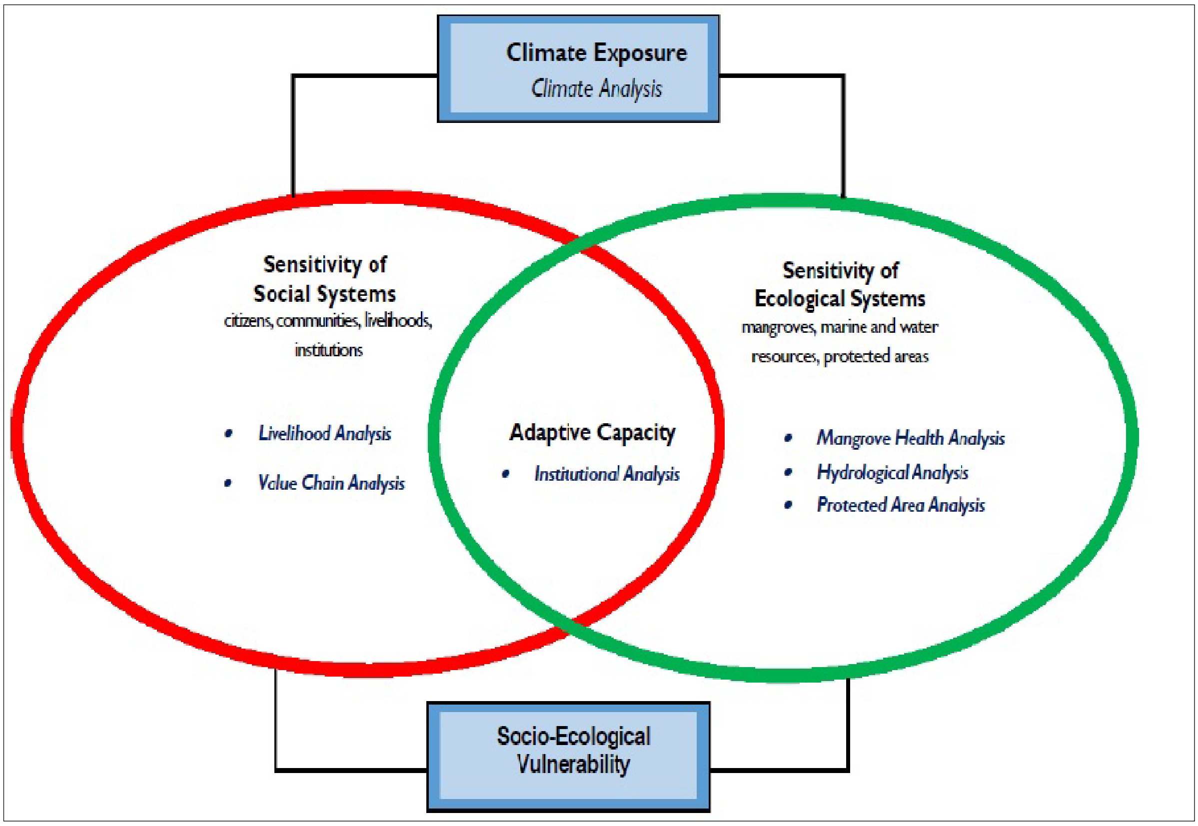
3.3 VULNERABILITY ASSESSMENT ANALYTICAL FRAMEWORK

The analytical framework for this climate change vulnerability assessment was the prism of socio-ecological systems (SES; Figure 3), which can be defined as integrated systems of ecosystems and human society with the whole issue of mutual feedback and interdependence. Social systems refer to individuals, households, communities, livelihoods, institutions and networks that shape human society, while ecological systems refer to the resources that make up the natural environment (land, water resources, forests and watersheds, etc.).

The concept of SES recognizes the interaction and interdependence of humans and nature and the dependence of individuals and communities on ecosystem services for their livelihoods. Thanks to this methodological framework, the three dimensions of vulnerability could be documented by combining climate modelling (exposure), household surveys and focus groups to assess and evaluate the sensitivity of socio-ecological systems (SES) to climate change and finally measure the adaptive capacities of both communities and institutions.

Recognizing the complexities associated with quantifying, measuring and assessing the state of the Fresco coastal landscape, the vulnerability assessment is focused on climatic, ecological, hydrological aspects, including the physico-chemical quality of water resources, as well as social, economic, cultural and institutional aspects. Based on the situational analysis of these dimensions of vulnerability associated with a geospatial assessment, an integrated vulnerability assessment of the Fresco lagoon landscape is then developed.

Figure 3: Socio-economic research framework and analytical component



This methodological framework makes it possible to answer the three (3) scientific questions considered in this vulnerability assessment, namely:

1. how is climate change impacting/ (will impact) coastal habitats (coastal forests, mangroves, rivers) and marine resources? **(exposure)**
2. how have these impacts affected / (will affect) the Fresco Lagoon landscape and the socio-economic system of the basin? (**sensitivity**)
3. how people and institutions respond/can respond and adapt to these impacts? (**adaptability**)

This research is implemented through four (4) distinct but interconnected analytical components: (1) climate (2) ecosystems (including mangroves, forests, water resources, and the connection and interactions between these ecosystems) (3) livelihoods based on natural resources or derived from ecosystem services (sustainable options, mangroves, forest resources and fisheries value chains) and (4) institutions. The analytical components of the assessment will be grouped into an integrated approach to assess the vulnerability of ecosystems and human populations, with a view to better adapt to climate change.

Nonetheless, it should be noted that this analytical framework essentially presents a limitation of the adaptive capacity to the institutional analytical capacity, while communities, or even households and even individuals, have adaptive capacities. Moreover, we agree with the IPCC (2014) that adaptive capacity is defined as the "ability of systems, institutions, people and other bodies to ***adjust***, to ***protect*** themselves against possible damage, ***to take advantage of*** opportunities or to react to consequences".

To this end, challenge for any organization or ecosystem is not only to protect itself against damage of any kind, but also to take advantage of opportunities, even if it means turning challenges into opportunities. Vulnerability was initially seen as *"the degree to which a system is likely to, or is unable to, cope with the adverse effects of climate change, including climate variability and extreme weather events (IPCC, 2001; CARE International, 2009), Vulnerability depends on the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity. "In this context, "exposure to climate change is primarily a matter of geographical location. For example, communities living along the coast will be more exposed to sea-level rise and cyclones, while those living in semi-arid areas will be more vulnerable to drought. Sensitivity is the degree to which a community is affected by climate stresses. A community dependent on rainfed agriculture will be much more sensitive than a community whose main livelihood is mining, for example" (CARE International, 2009). The work of the 5th IPCC Report (IPCC, 2014) tells us that exposure refers to the "presence of people, livelihoods, species or ecosystems, environmental resources and services, infrastructure or economic, social or cultural goods in a place likely to suffer damage. This conceptual evolution is more globalizing. The same is true for vulnerability, which is rather considered as the "propensity or predisposition to suffer damage. This includes various concepts, including the notions of sensitivity or fragility and the inability to cope and adapt." (IPCC, 2014).*

This study uses a mixed-method approach (which has proven its effectiveness); it allows existing secondary data to be taken into account as well as primary data collection (household surveys, focus groups, in situ measurements or data, etc.).

3.3.1 HOUSEHOLD SURVEYS

To carry out this assessment, a number of criteria for site selection were defined. Regarding household surveys, 10 communities out of a total of 23 in the Fresco Lagoon region were selected. As a matter of fact, without resorting to geographical location, the communities were selected according to their proximity to the reference community, namely Fresco and its lagoon. Thus, from Fresco, distance buffer zones were defined, namely from 0 to 10 km, from 11 to 20 km and beyond 20 km. As shown in Figure 4, the communities in the first radius (within 10 km) around Fresco are: Fresco, Zakerako, Bouiko, Fisherman camp1 and Zegban. In zone 2 (11-20km), Zuzuoko, Daliziele and Dahiri were selected. Finally, the third group refers to the communities in Zone 3 (beyond 20 km around Fresco). This includes Dassioko and Kosso. For focus groups, a total of five communities were selected: in zone 1, three (3) communities were selected; in zones 2 and 3, one community in each was selected. It is obvious that such a choice of sampling of villages to be surveyed could have limitations when it comes to the unequal number of villages per zone, but when we are interested in climate change issues, particularly vulnerability and knowing the place of sensitivity and exposure to climate hazards, geographical discrimination in terms of distance from the waterfront is important insofar as villages in the interland would not be affected in the same way.

A structured questionnaire pre-installed in Samsung © digital tablets, using CSpro © software, was administered to 438 households in the Fresco lagoon landscape (Figure 4; photo sheet 1). The said questionnaire was pre-tested before being deployed on the field. The questionnaire was administered in a non-random but in a well-defined manner, and covered perceptions about climate change and extreme weather events, decline of ecosystem services, state of socio-economic livelihoods and crop value chains.

The questionnaire was supplemented by focus group discussions, key informant interviews as a means of triangulating data. One respondent per household (preferably the head of the household or any available adult willing to participate in the survey) was interviewed. The answers were entered into the tablet questionnaire).

Figure 4: Survey site of the Fresco lagoon landscape

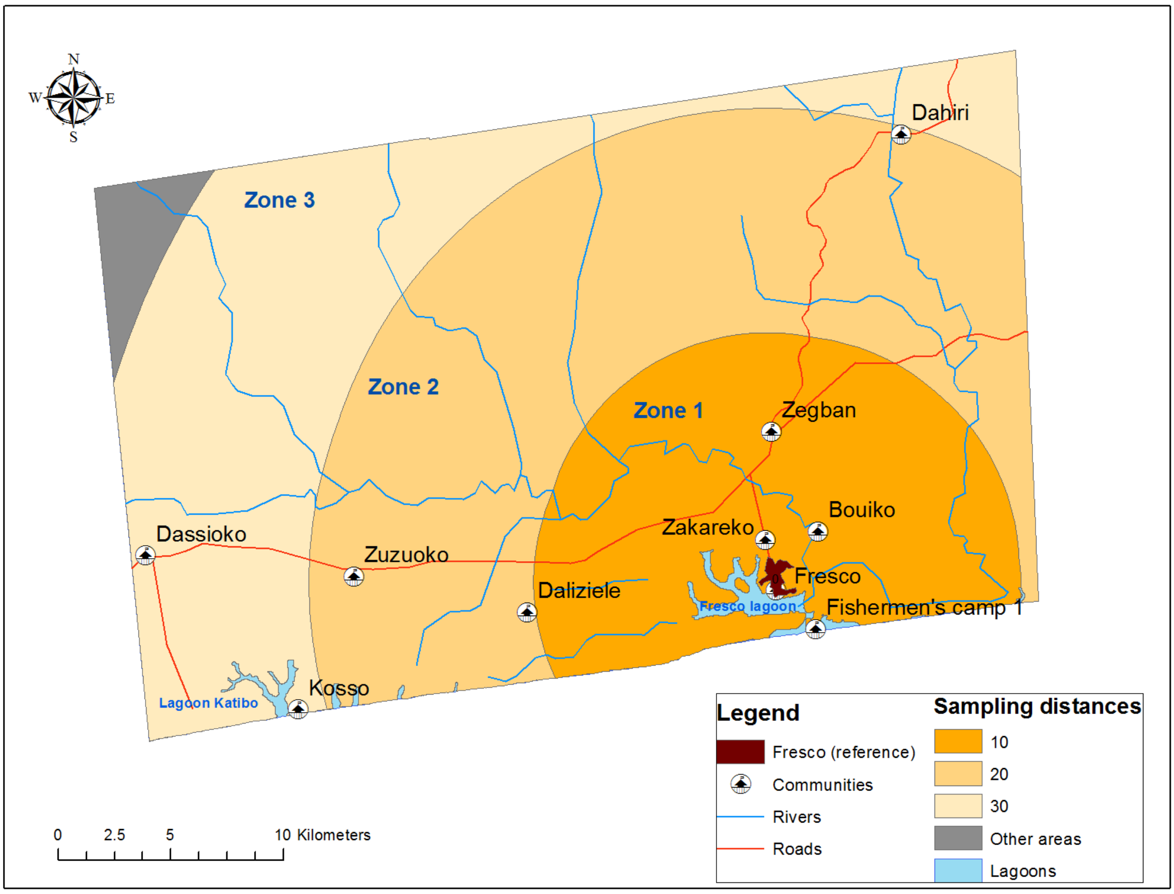


Photo gallery 1: photos showing primary data collection process in the Fresco lagoon landscape

		
Household survey in Fresco	*Focus group* in Dassioko	*Focus group* in fishing communities
		
Collection of GPS coordinates for mapping (land use and occupancy)	Measurement of the width of vegetation destroyed at station 6 (mangrove data)	Measurements of physico-chemical parameters of water in situ in a well in Fresco

Source: UNU-INRA, 2018

3.3.2 CLIMATE ANALYSIS

The Fresco region is poorly equipped with climate monitoring and observation stations under the responsibility of SODEXAM, which is the mandated body for climate data collection. It should be noted that at the regional level, rainfall data are available for Fresco and Gbagbam. Temperature data are available at the Sassandra synoptic station, which covers the entire Gboklè Region for all climate parameters except rainfall, which has a high spatial variability.

Photo 2: Rainfall station in Fresco (A) and Fresco Weather Station (B)

Source: Dje, 2018

The analysis of these data, in order to characterize past climate trends, is carried out by the RclimDex tool, which makes it possible to generate climate indicators from the series of maximum, and minimum rainfall figures at different times. The trends of seasonal distribution of rainfall was also analyzed.

For climate projections (Moss et al, 2008), the RCP4.5 scenario corresponding to the median scenario was applied using data from the Fresco weather stations. These climate scenarios, combined with CMIP5 data, were used in the preparation of Côte d'Ivoire's 3rd National Communication on Climate Change and by the National Meteorological Service (DJE, 2014).

This climate analysis was enriched by knowledge of farmers' perception of the current context of climate variability and its impacts on their activities, which required a field survey during the household surveys

3.3.3 HYDROLOGICAL ANALYSIS

For water resources analysis, the parameters used are monthly rainfall figures, monthly average temperatures, daily flows and physico-chemical parameters (temperature, pH, electrical conductivity, total solids dissolve NaCl level. They were measured in situ on 20 February 2018 at 19 points, at the surface, distributed over the Fresco lagoon, the Atlantic Ocean, and the Niouniourou and Bolo rivers supplying the lagoon and some wells in the city of Fresco near the lagoon (Table 7 below shows the coordinates of the measurement points for the physico-chemical parameters).

These parameters are used in particular to estimate the variation in water quality. The monthly rainfall levels are those of the Fresco station over the period of 1968-2017 and the monthly average temperatures are those of the Sassandra station over the period of 1960-2016. These data come from SODEXAM and have no gap.

The daily flows are those of the Niouniourou River at Dahiri station over the period of 1983-2004; they come from the Directorate of Hydrology, Standards and Quality. These flows have deficiencies that have been discounted at a monthly scale by linear regression with flows from the neighbouring Davo basin to Zakpaberi, as they have correlation coefficiency greater than 0.9.

Table 7: Measurement points for physico-chemical parameters

Measurement point numbers	Longitude	Latitude	Water type
16	-5.572111111	5.081444444	Sea
15	-5.573916667	5.081722222	Inlet (Sea-Lagoon)
14	-5.570444444	5.085833333	Lagoon
17	-5.569527778	5.082916667	
8	-5.574416667	5.091638889	
1	-5.580527778	5.095833333	
2	-5.58075	5.09475	
4	-5.5825	5.095916667	
19	-5.591861111	5.101305556	
9	-5.569431	5.090333333	Lagoon-River
10	-5.563611111	5.101916667	River
11	-5.562833333	5.105444444	
12	-5.560222222	5.105416667	
13	-5.565888889	5.107333333	
3	-5.582555556	5.096222222	wells
5	-5.581083333	5.098333333	
6	-5.580833333	5.098388889	
7	-5.582472222	5.09925	
18	-5.59175	5.101305556	

The data collected for this hydrological analysis have some limitations that should be pointed out. The extent of hydroclimatic series is not sufficient: the rainfall series begins in 1968, two years before 1970, which is the year of general rain break in West Africa, and the series of daily flows of the only gauged river begins in 1983 and ends in 2004 due to lack of monitoring. The spatial coverage of hydroclimatic parameters at measuring stations is very low to be able to estimate their average values, which better reflect variations at the scale of the catchment area. There is also a lack of measuring stations on the lagoon that is the subject of the study and on the Bolo River that flows directly into it.

The duration of the field study in Fresco made it possible to carry out a single measurement campaign of the physico-chemical parameters of the lagoon during the main dry season. In the future and to improve the scientific quality of this work, it would be appropriate to: (i) instrument the lagoon and surrounding rivers with automatic and multi-parameter stations; (ii) increase the number of measurement stations in the Fresco area; (iii) monitor these stations; and (iv) carry out measurements of physico-chemical parameters during the two rainy seasons and the two dry seasons to have a better appreciation of the variation in physico-chemical parameters.

From tool standpoint, the following were used: (i) a Hanna portable conductivity meter and a Hanna portable pH meter were used to measure physico-chemical parameters from boats for certain points; (ii) the IRD KhronoStat version 1.01 software allowed the Pettitt test to be applied on the Fresco rainfall series and (iii) the Cemagref GR2M model programed in Microsoft Office Excel (version 1.0) proposed by Mouelhi et al. (2006). This is a globally conceptualized model with two optimizable parameters used to determine the hydrological balance.

For statistical analysis, we used the following:

i. the calculation of dispersion variables such as the range of variation;

ii. the coefficient of variation;

iii. the calculation of ten-year averages to assess the importance of interannual variability within time series;

iv. the application of the Pettitt test (Lubès-Niel et al. 1998) on the series of annual rainfall levels to detect the presence of a break in a homogeneous period;

v. drawing trend curves;

vi. the calculation of weighted moving averages, centred and reduced which eliminates seasonal variations within series and clearly shows interannual trends;

vii. calculation of monthly averages of rainfall levels per period;

viii. calculation of average flows;

ix. the determination of dry months by periods to assess seasonal variations;

x. the drying coefficients;

xi. the volume of the hydrogeological reserve likely to supply the surface runoff is calculated for each hydrological year with the objective of showing how the surface-water - groundwater relationship has been affected by variability in rainfall;

xii. rain-flow simulations are carried out over rolling 62-month periods to find the one where the model best reproduces the hydrological behaviour of the Niouniourou watershed in Dahiri. From this simulation, the model is used in extrapolation and interpolation to fill gaps and extend the series of monthly mean flows. The GR2M model conceptualizing the basin into a series of interconnected reservoirs makes it possible to calculate the water balance of the watershed;

xiii. the evolution of physico-chemical parameters such as salinity, temperature, pH, TDS from the lagoon to the ocean, rivers and wells to quantify variations in physico-chemical parameters in and around the lagoon.

3.3.4 STUDIES ON COASTAL FORESTS AND MANGROVES

Two types of methods were used to study plant formations:

Topographic method of transects

For the study of mangroves, we used, as did Traoré (1985) and Egnankou (1985), the scalled "topographic method of transects" by Duvigneaud (1969), cited by Egnankou (1985). A total of nineteen (19) stations were visited and fifteen (15) transects were studied;

Itinerant coastal forest inventory

For the mainland forest, the vegetation study was done by the 'itinerant inventory' method. Then, we collected the main environmental parameters by direct observation, which are (i) the level of degradation of the site; (ii) the number of strata included in the vegetation; (iii) the type of vegetation; and (iv) hydromorphy. These different factors were chosen because they vary from one site to another and from one observation to another. They will explain the presence or absence of recorded species. To measure the degradation of each plot and the entire site, we have chosen a degradation scale ranging from 0 to 100%.

3.3.5 CHANGES IN LAND USE AND OCCUPANCY MAPPING

Data used for mapping land use and occupancy changes included satellite images, GPS field data, secondary maps and Google Earth images from 2017 to facilitate the categorization of the landscape.

To understand the historical dynamics of occupancy and land use coverage under the combined influence of natural environmental change and human activities in the Fresco landscape, we used the Landsat satellite data series (Landsat-5 TM (1990) and Landsat-8 OLI TIRS (2017)) downloaded from the USGS Earth Explorer online data exchange centre (http://earthexplorer.usgs.gov; (table 8). The criteria used to select the images remain geographical location, temporal relevance and low cloud cover (less than 10%) per image. To this end, two images were extracted from the Landsat database and considered appropriate for the study area. Although the images are of different dates, they all are from the dry season, therefore, essentially comparable.

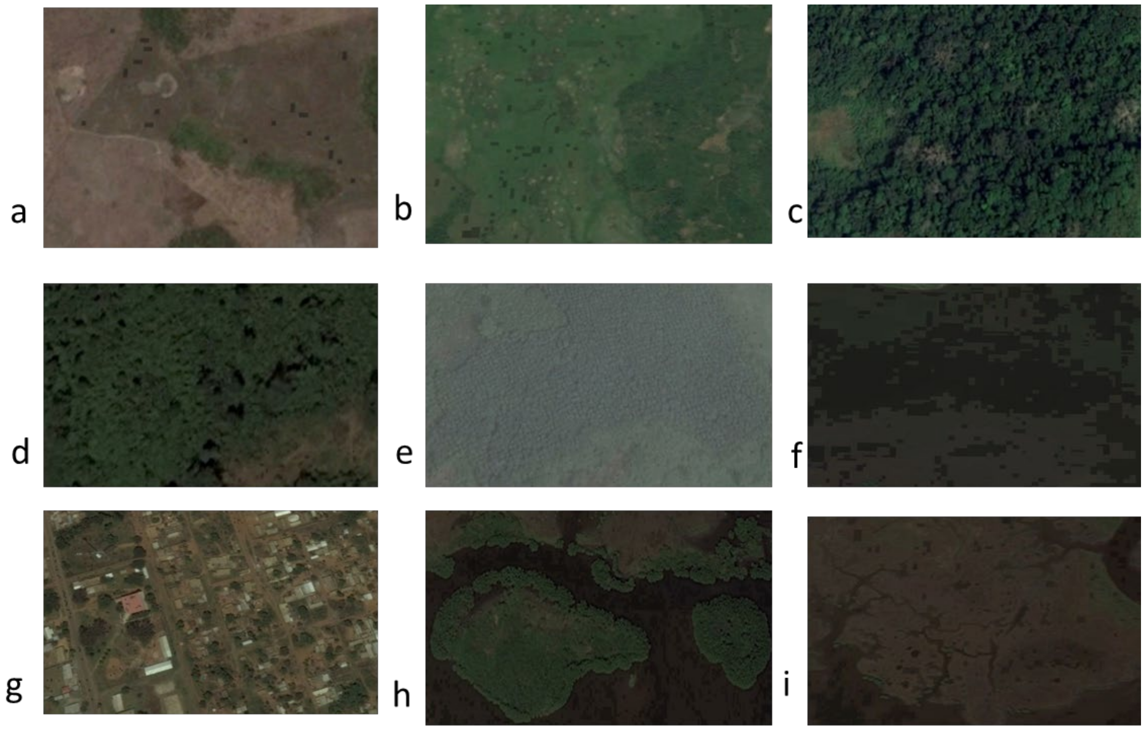
Table 8: Properties of the satellite data used in this study

SCENE_ID	Sensor	Column/ Row	Date	Cloud coverage	Comments
LC81970562017357LGN00 (Band range: B2 – B7)	Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS)	197/56	2017/12/23	0.08	Total coverage
LT51970561990363MPS00 (Band range : B1 – B5 and 7)	Thematic Mapper	197/56	1990/12/29	6.00	Total coverage

Also, field data collection was carried out on 22nd and 23rd February 2018. The purpose of this field data collection was to sample the main categories of land occupancy and use coverage of the Fresco lagoon landscape. To this end, polygons with their GPS coordinates (731 points) were collected in types of cover of interest and described and, where possible, photographs were taken as attributes of the location (Table 9). The borders of the coverage types were deliberately avoided to reduce the edge effect of mislabelling land use and occupancy categories to improve the reliability of the data.

Secondary data (not based on satellite images) and mainly maps of mangrove areas in the Fresco landscape for the years 1985 and 1991 (Egnankou. 1991) were also acquired to provide a historical overview of the trend in the Fresco landscape environment in the 80s and 90s. In addition to field data, recognizable land cover categories from Google Earth's historical and current high-resolution data were also extracted to improve image classification and accuracy assessment processes (Figure 5). Google Earth's high-resolution data were mainly used to compensate for areas in the landscape that were inaccessible for ground data collection due to distance and natural obstacles. Land use and occupancy coverage characteristics were identified using Google Earth data. Visually distinct areas were digitized and assigned to classes based on image interpretation elements such as shape, tone, texture, pattern, colour and association. This was achieved by scanning visually distinct areas on the screen.

Figure 5: a) farming area. b) Forest reserve. c) woodland. d) Rubber. e) Cocoa. f) Water. g) Urban areas. h) Mangroves and i) Wetland areas



Since Landsat surface reflectance images are already pre-processed using atmospheric parameters and a DTM (Digital Terrain Model) to reduce atmospheric effects on the images, additional but minimal pre-processing has been performed (Young et al... 2017). For both images, fog remains were removed by the DOS application (dark object subtraction; Gilmore. et al... 2015). The average reflectance of water was not used as a subtraction factor as suggested by Gilmore et al. (2015). On the contrary, the minimum reflectance values of each band of the set of images were extracted using raster statistics and applied. The image strips resulting from the DOS were respectively superimposed in their entirety on other composite images. Using conventional displays with ENVI 5, the cursor was used to determine the locations of identifiable tracking features common to both images to ensure that they are synchronized and geographically positioned. The data sets that were in Zone 29 UTM. WGS-84 (North Datum) were superimposed on the shapefile of the study area and cut to the predefined location.

A well-defined classification scheme is fundamental to the success of any project to categorize, identify occupancy and land use coverage. Even better, a golden rule for the implementation of a good system is the mutual exclusivity of information categories. For this study, the main types of occupation categories of the Fresco lagoon landscape were identified and grouped into mapping classes with their definitions. The objectives of the study, the spatial resolution of the images (30 m) used and previous studies in the area guided some of the choices. The grouping resulted in nine mapping classes (Table 9).

Table 9: Summary of occupation and land use categories

Land use and occupancy category	Mapped categories	Description of the class in the landscape
Continuous forest cover	*Forest*	*Wooded areas with dense tree cover occupying more than 0.5 hectares with trees greater than 5 metres in size. This includes forests in and outside conservation areas but excludes plantations meeting these criteria*
	Open forest	*Degraded wooded areas with dense tree cover occupying more than 0.5 hectares with trees greater than 5 metres in size*
	Mangroves	*Area of forest and other wooded land with mangrove vegetation (Aviceana spp.) found along watercourses.*
Annual and biennial crops. *Gardening Fallow*	*foodcrop*	*Portions of the landscape that are arable and planted with annual or bi-annual temporal crops and without permanent cash crops. This class includes fallow areas that are in series with the growing periods*
Bushes and grasses	*grassland*	*A grassland can also contain low shrubs and other plants. But its predominant characteristic is that it is a place where a lot of grass grows.*
Rivers *Streams* *Lagoons* *Lakes* *Stagnant water*	*Water*	*Refers to all forms of water bodies in the study area. i. e. streams. lagoon. standing water bodies. etc.*
Bushes *Grasses* *Water-soaked lands (swamps)*	*Wetland*	*Areas of land flooded during a certain time of year. i.e. swampy grasslands may sometimes have other bushes*
Cocoa or coffee plantation *Rubber* *Citrus fruits* *Coconut oil palm plantation*	*Plantation*	*Refers to areas of plantation crops that produce outputs over many harvest seasons and last longer on the land. Usually planted for commercial interests.*
Built areas	*Built / bare ground*	*Minimal. isolated and non-vegetated parts of the landscape. including built. bare. rocky areas. including beaches and mining areas in operation.*
Bare areas. rock outcrops. sandy beach		

Image classification is an important part of detecting changes in a landscape. It refers to a process of grouping image pixels according to similarities in predefined significant land cover categories. The Fresco landscape is tropical by nature; it remains very fragmented and composed of very heterogeneous land use types. The complexity or even the entanglement of the different land use categories makes it difficult to use a traditional algorithm to obtain a representative classification. An unsupervised and supervised hybrid classification was used in the categorisation (Wondrade et al. 2014).

The images are spectrally segmented into 50 categories, each using the K-means unsupervised classification algorithm in the ENVI software. The unsupervised classification algorithm statistically groups the pixel of images into a given number of pixel values based on spectral classes rather than comparing them with reference data (Lu and Weng 2007). Therefore, the larger number of classes allows the separation of spectrally similar but different classes. The final card classes were then obtained by manually merging similar classes. While the 1990 map was documented by historical maps of Egnankou (1991), the 2017 map was documented by field data and Google Earth data.

3.3.6 INSTITUTIONAL ANALYSIS

Institutional data were collected from primary and secondary sources. For primary data, individual interviews and discussions with key institutions in the region were conducted to identify their roles in the climate change adaptation process in the region. An interview guide was used to collect specific data on the characteristics of institutions and their actions in adapting to climate change.

The overall objective of the primary data with institutions is to know how institutions in the region contribute to community livelihoods and their roles in climate change adaptation. They also aim to determine communities' perceptions of institutions and their roles in livelihoods and adaptation to climate change. How were the institutions sampled? First, a list of all the institutions in the region was drawn up by the local authorities, taking into account their specificity, fields of action and importance at the local level. Then, several institutions were selected, namely: The Directorates representing the technical ministries, farmers' associations. NGOs etc. In addition, given the unavailability of all stakeholders, fifteen (15) institutions in the region were interviewed. The qualitative data collected from these institutions were processed and analysed using the SPSS statistical software.

This primary data collection was complemented by a literature review that analysed various approaches to the role of institutions in reducing the vulnerability and adaptation of communities and other key stakeholders to climate change. This case study in Fresco is important to know how households and institutions interact with each other and with communities to ensure that the region is more resilient to climate change.

3.3.7 DATA ANALYSIS AND INTEGRATION METHOD

Once the survey data were downloaded from the tablets, they were consolidated into MS Excel and SPSS packages for analysis (simple summaries, cross-tabulations and analysis of the relationships between phenomena were performed). Data compilation, analysis and integration were consolidated, bearing in mind the intertwining of the components as described in the HSE methodological framework. However, there are structuring or acting factors that are more familiar to Driving Forces that preside over or may even exacerbate ongoing changes, including climate change. Indeed, climate through its twofold dimensions (climate variability and projections) is the starting point for vulnerability analysis since the diversity of climate hazards will affect the Fresco region in different ways and with varying intensities. This will have repercussions first on ecosystems, threatening ecosystem services that provide the bulk of the income of local communities for their livelihoods. It is at this point that we will be able to assess the socio-ecological sensitivity of ecosystems through value chain analysis, livelihoods, water resources, mangrove conditions and changes in land use and occupation based on satellite imagery. Nonetheless, it should be noted that adaptation activities are carried out as constraints emerge; this third dimension of adaptive capacities concerns responses from both communities and institutions. Hence, the sum of all this allowed us to assess the vulnerability of the Fresco lagoon landscape to climate change.

3.3.8 VALIDATION OF RESULTS AND OPTIONS ANALYSIS

The presentation of the main conclusions as well as the validation of the results of the assessment report were discussed with invited stakeholders who made their contributions during the validation workshop held in Fresco, Côte d'Ivoire, on the 13th and 14th of April 2018 (photo gallery 2).

Photo Gallery n° 2: Pictures of the validation workshop held in the premises of the Fresco Town Hall on 13 and 14 April 2017

		
An overview of Group 1 of experts who worked on the theme "Climate analysis and expected climate impacts on populations and ecosystems".	An overview of Group 2 of experts who worked on the theme "Vulnerability of ecosystems. including mangroves and livelihoods from natural resources".	An overview of the group 3 of experts who worked on the " theme "Institutions"
		
A view of community and stakeholder representatives during the validation workshop held in Fresco on 12 and 13 April 2018. in the presence of the Prefecture and municipal administrative authorities and experts.	A view of the high-table at the opening ceremony of the validation workshop held in Fresco on 12 and 13 April 2018 in the presence of the administrative authorities, municipal authorities, representatives of the WABICC project and the United Nations University – Institute for Natural Resources in Africa (UNU-INRA) based in Accra (Ghana).	

4.0. RESULTS

4.1 EXPOSITION

4.1.1 CLIMATE TRENDS

4.1.1.1 Rainfall

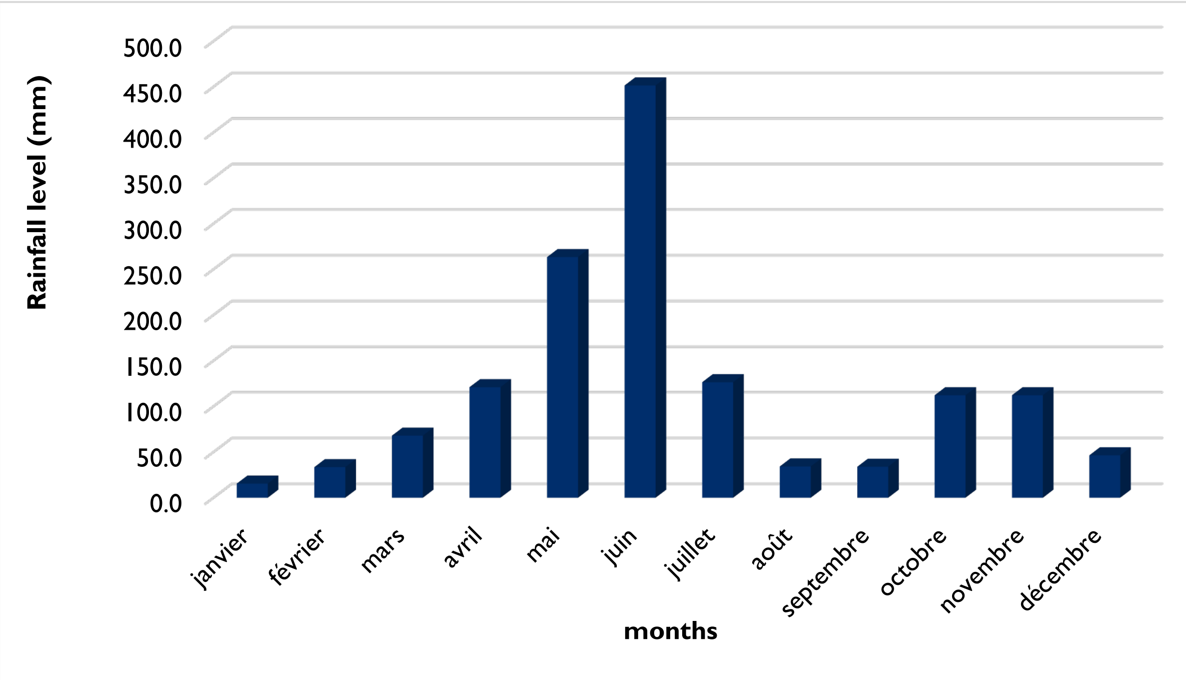
Rainfall Characteristics

The rainfall regime of the region is of the bimodal type characterized by 4 seasons:

- a long rainy season from March to July with the maximum rainfall in June and an average of 463 mm;
- a short dry season from August to September with rainfall level below 50 mm;
- a short rainy season from October to November;
- a long dry season from December to February when rainfall level remains below 50 mm.

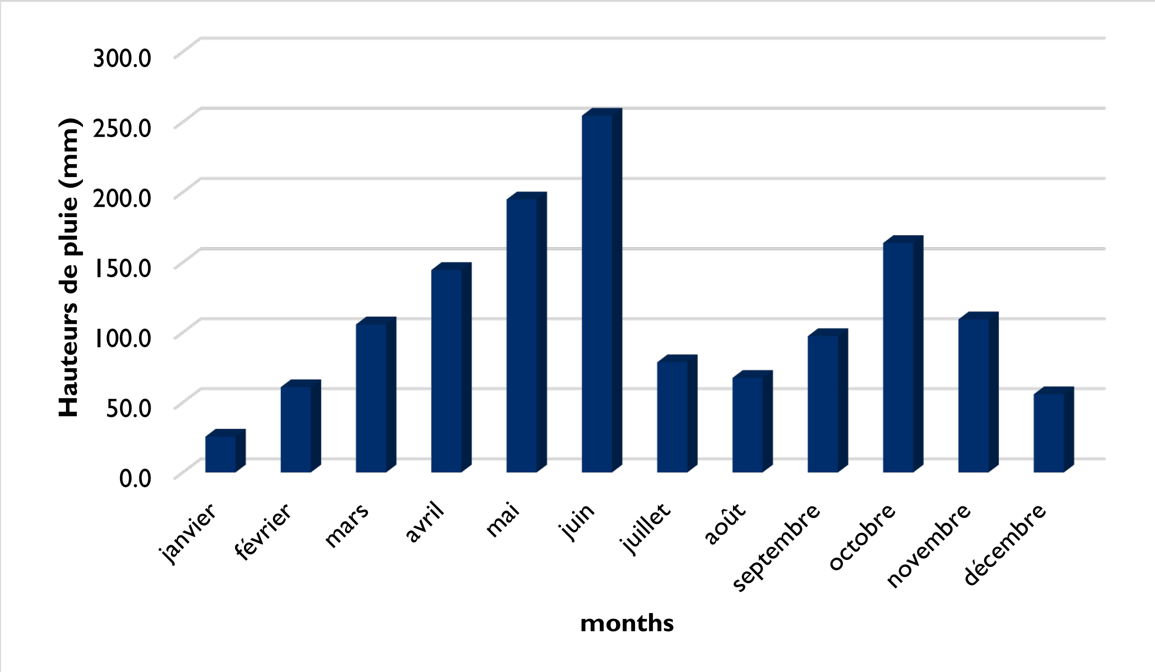
Figures 6 and 7 show the annual trends in rainfall in Fresco and Gbagbam over the period of 1971-2000.

Figure 6: Cumulative monthly rainfall trends of Fresco over the period of 1971-2000



Source: Data from SODEXAM

Figure 7: Cumulative monthly rainfall trend at Gbagbam over the period 1971-2000



Source: Data from SODEXAM

The annual rainfall levels were determined from the two stations. The average annual rainfall in the study area is 1388.2 mm. The 1971-2000 rainfall normals for Fresco and Gbagbam are 1410.0 mm and 1358.3 mm respectively. The seasonal characteristics of rainfall are summarized in the following Table 10.

Table 10: Seasonal characteristics of rainfall in the Fresco region

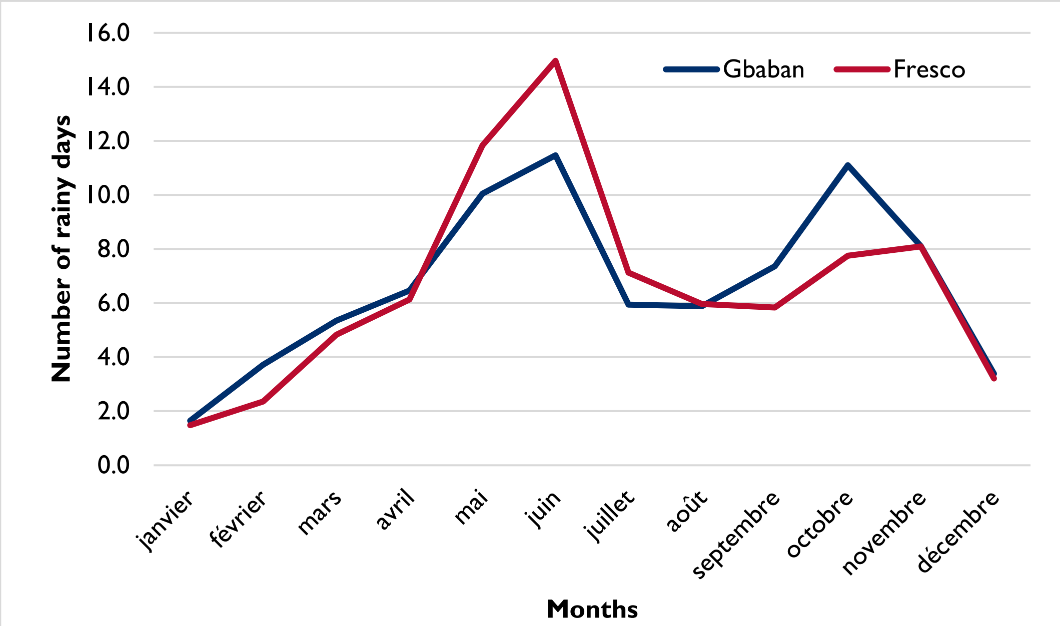
Station		Period	Cumul (in mm)	Annual Contribution (in %)
Fresco	1st rainy season	March to July	1030.2	73
	1st dry season	August to September	68.1	5
	2nd rainy season	October to November	224.3	16
	2nd dry season	December to February	95.3	6
Gbagbam	1st rainy season	March to July	778.1	57
	1st dry season	August	67.5	5
	2nd rainy season	September to October	370.4	27
	2nd dry season	November to February	142.3	10

Source: Data from SODEXAM

Seasonal analysis of rainfall over the period of 1971-2000 normals shows that more than 73% of the year's cumulative rainfall in Fresco is recorded during the 1st rainy season while the 2nd rainy season records only about 16%. For Gbagbam, the first season contributes 57% to the year-to-date records and the second season 27%.

The annual totals of the number of rainy days over the normal period of 1971-2000 are 80 days for the Fresco and Gbagbam rain stations. The type of climate to which the Fresco region belongs means that there is at least one rainfall in the month, whatever the season. Figure 8 shows the average change in the number of rainy days in Fresco and Gbgbam over the years.

Figure 8: Trends in the number of rainy days in Fresco and Gbagbam over the period of 1971-2000



There is a good relationship between the number of monthly rainy days and the seasons. Thus, the long rainy season corresponds to the period with the highest number of rainy days followed by the short rainy season. The short dry season and the long dry season are the periods when the number of rainy days is low compared to the two rainy seasons.

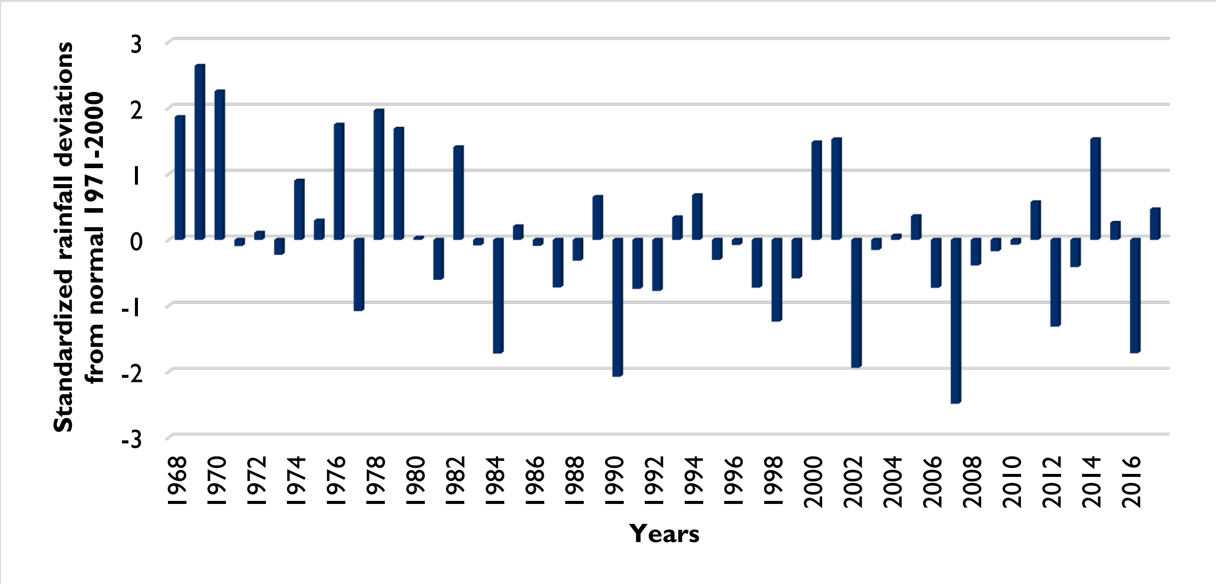
.

Rain measurement: Variability and Projections

In terms of rainfall, Côte d'Ivoire has experienced many fluctuations since the 50s. As a matter of fact, the 1950s and 1960s were relatively wet while the 70s to the 90s were dry. These observations have been documented and confirmed by studies by Brou (1997) and Paturel et al (1996). Analysis of the 1971-2000 normal compared to that of 1961-1990 shows an average reduction in rainfall of 6% over the entire Ivorian territory, with remarkable decreases of 13% in the southwest and 11% in the southeast. Rainfall has been particularly low since the 80s compared to the 1951-1980 average (Nguessan and Djè. 2012; figure 9).

Annual rainfall levels vary from year to year and the relative deviations from average precipitation (coefficient of variation) are 29%. Annual or seasonal rainfall totals reflect the variability of intra-seasonal rainfall characteristics such as the occurrence, stopping and distribution of rainy days and dry periods as well as extreme precipitation, with significant impacts.

Figure 9: Standardized annual rainfall level anomalies to normal 1968-2017 at Fresco

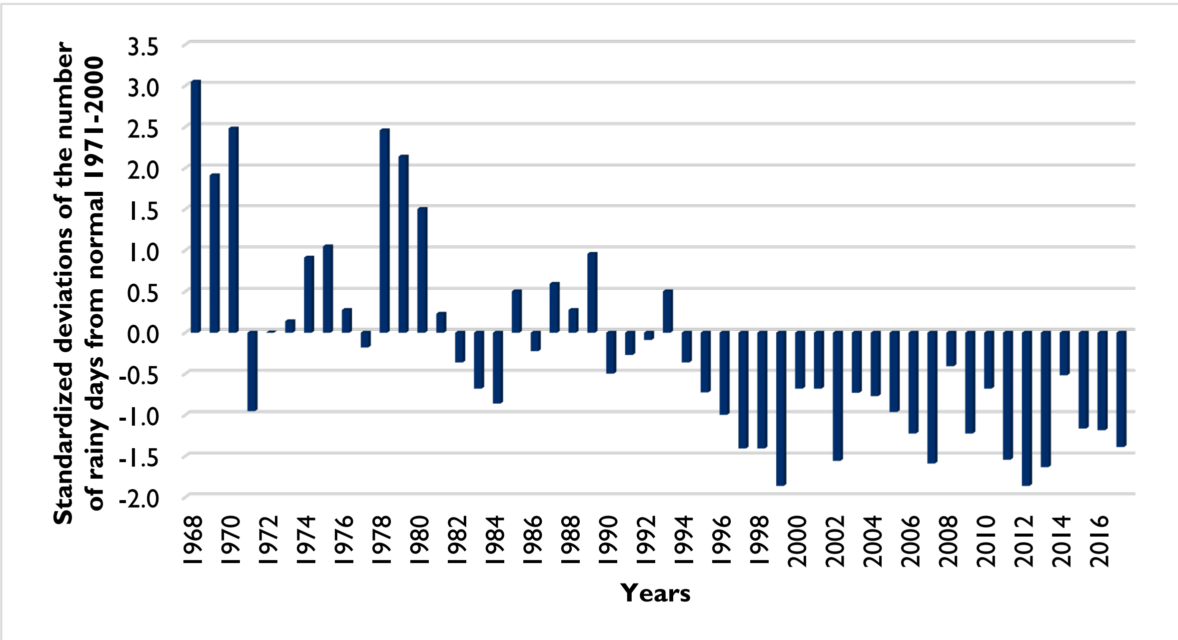


Source: Data from SODEXAM

Analysis of the accumulation of precipitation from 1971 to 2017 at Fresco does not show a clear trend in the accumulation of rainfall during this period.

Over the period of 1971-2000, the average number of rainy days was 79. This number has been subjected to significant interannual variability, particularly since the mid-1990s, when the number of rainy days has drastically decreased. During the normal 1981-2010 period, this number fell to 66, a decrease in the normal during the 1981-2010 period, of 16%. Figure 10 shows the normalized differences in the number of rainy days per year over the period 1971-2010.

Figure 10 Standardized deviations of annual rainfall days from normal 1968-2017 at Fresco

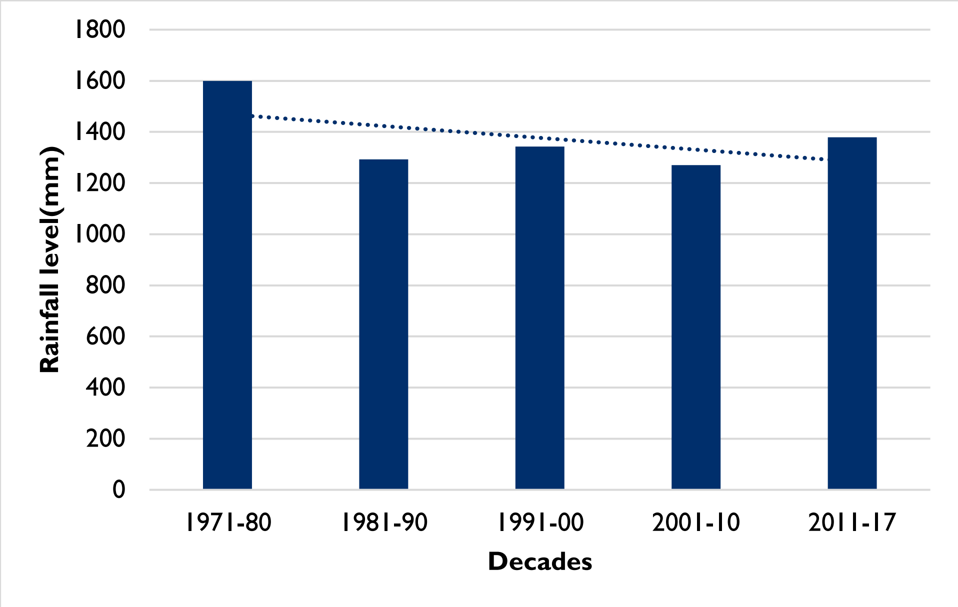


Source: Data from SODEXAM

There is also a 36% increase in rainfall intensities, which shows the increasingly extreme nature of rainfall events. It appears that on a seasonal scale, the trend is downward. This observation is the same for the distribution of rainy days. For the main rainy season (April to July), a decrease in the number of rainy days estimated at 12% has been observed since the early 90s.

This downward trend in annual rainfall also appears on a ten-year scale (Figure 11).

Figure 11 : Variations in average rainfall amounts per decade for Fresco

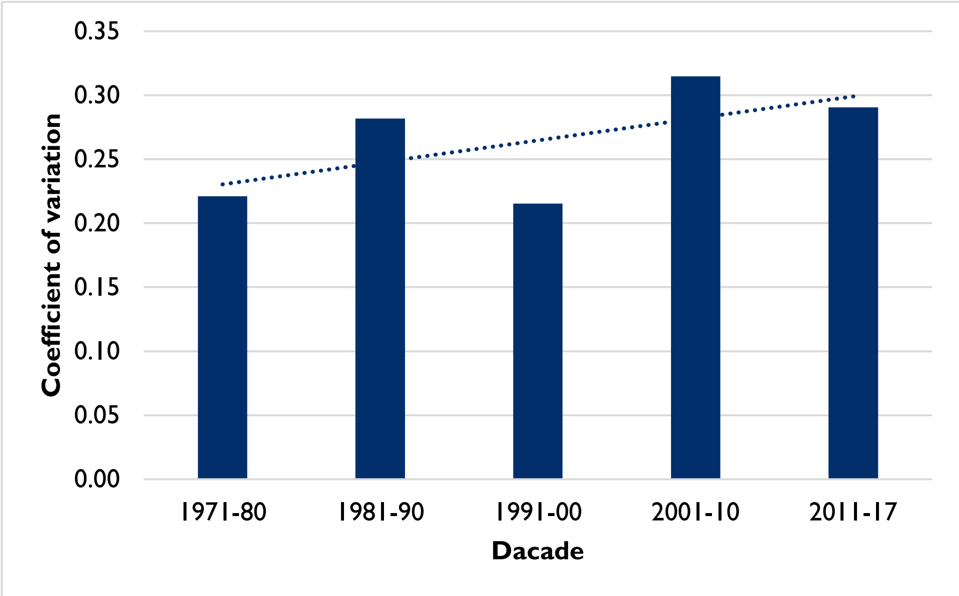


Source: Data from SODEXAM

The average annual rainfall for the 70s (1599.0 mm) remains more than 100 mm higher, despite some fluctuations, than in other consecutive decades, which range from 1270.0 to 1379.0 mm. The 2000 decade was the one with the lowest average annual rainfall (1270.0 mm).

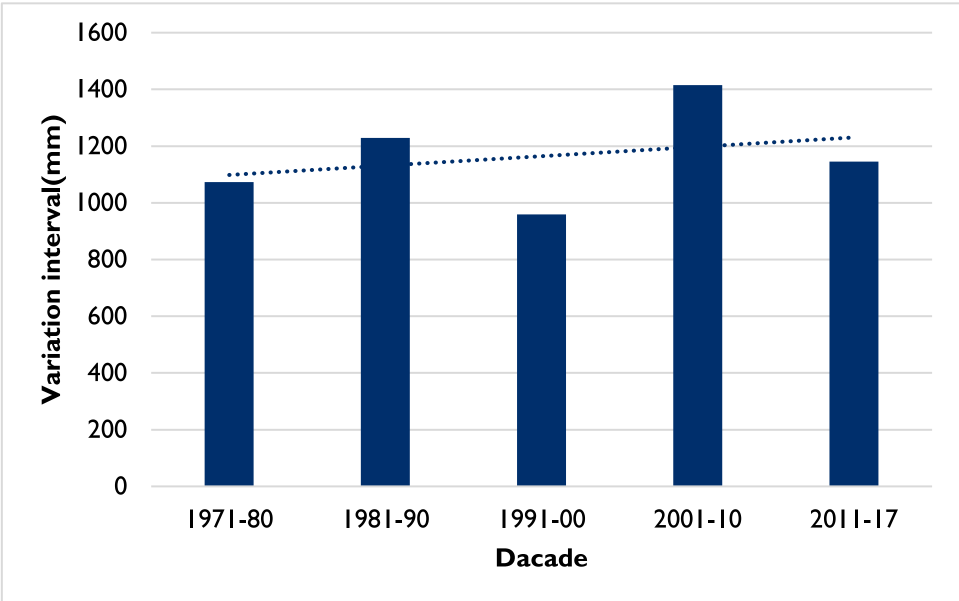
The interannual variability of annual rainfall increases overall with its decrease. Indeed, the coefficient of variation of the annual rainfall series of the 70s, which was 0.22, increases overall from 0.22 to 0.31 over the following decades (Figure 12). The same applies to the intervals of variation of the 10-year series of annual rainfall levels (Figure 13).

Figure 12: Variations in the coefficient of variation of annual rainfall levels per decade at Fresco



Source: Data from SODEXAM

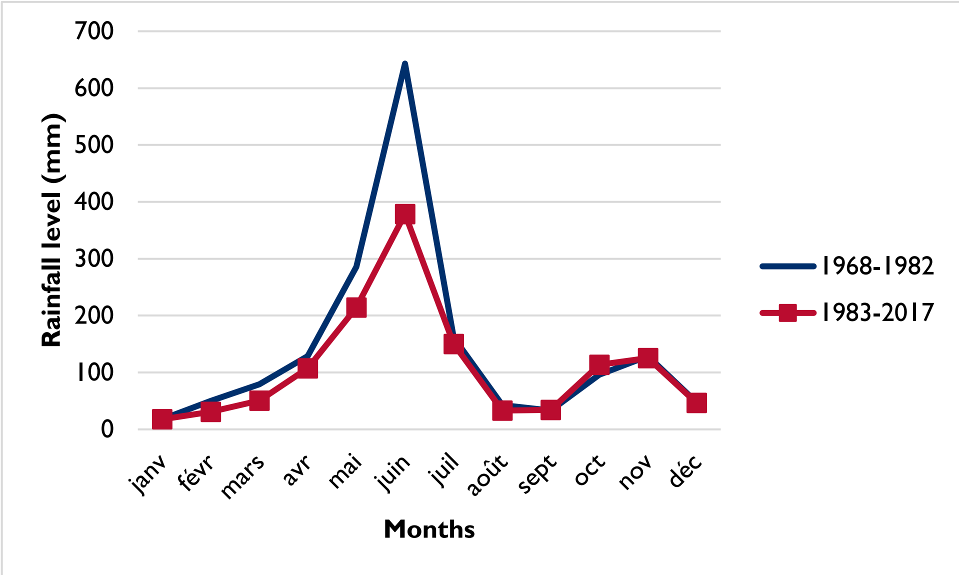
Figure 13: Evolution of the variation intervals per decade of the Fresco annual rainfall series



Source: Data from SODEXAM

On a monthly basis, the decrease in rainfall is also noticeable. The transition from a relatively humid period (1968-1982) to a consecutive period (1983-2017) is shorter in relation to the latter, leading to a general decrease in the quantities of water recorded on average per month in Fresco except for the months of October and November (Figure 14). This variation is more pronounced for the peak of the high rainy season when rainfall drops from 643.0 to 379.0 mm, representing a deficit of 41%.

Figure 14: Variations in average monthly rainfall levels from 1968-1982 to 1983-2017, which was in deficit compared to the previous period



Source: Data from SODEXAM

By combining temperature variations to determine dry months (Table 11), the division of the year into four seasons is appropriate. With the decrease in rainfall over the period 1983-2017. Two rainy seasons still alternate with two dry seasons in Fresco. but March becomes a dry month (Table 12). From now on, the main dry season extends by one month (December to March) and the main rainy season is shortened to April to July. Analysis on a smaller scale, i.e. by decade, shows that this change in the seasons begins to appear from the decade 2000 onwards (Table 13). Undeniably, from this period onwards, the average annual rainfall (P) becomes less than twice the average annual temperature (2 T).

Table 11: Rainfall levels and monthly average temperatures over the period 1968-1982

Month	Rainfall level (P) in mm	Temperature (T) in °C	2 T	Type of mois
January	17.8	25.9	51.7	*dry*
February	50.0	26.2	52.5	*dry*
March	79.0	26.6	53.2	*humid*
April	128.6	26.7	53.3	*humid*
May	285.6	26.1	52.3	*humid*
June	643.2	24.9	49.9	*humid*
July	161.3	24.1	48.2	*humid*
August	42.5	23.5	47.0	*dry*
September	33.3	24.0	48.0	*dry*
October	96.1	25.0	50.0	*humid*
November	129.0	25.8	51.7	*humid*
December	47.7	25.3	50.6	*dry*

Source: Data from SODEXAM

Table 12: Rainfall level and monthly average temperatures over the period 1983-2016

Months	Rainfall level (P) in mm	Temperature (T) in °C	2 T	Type of month
January	18.2	26.2	52.3	*sec*
February	29.2	26.8	53.5	*sec*
March	51.9	27.1	54.2	*sec*
April	109.8	27.3	54.5	*humid*
May	218.3	26.7	53.3	*humid*
June	374.7	25.6	51.2	*humid*
July	144.6	24.7	49.5	*humid*
August	33.6	24.0	48.1	*sec*
September	34.9	24.6	49.3	*sec*
October	111.8	25.6	51.2	*humid*
November	120.8	26.4	52.8	*humid*
December	47.3	26.3	52.7	*sec*

Source: Data from SODEXAM

Table 13: Rainfall variations and average March temperature by decade

	1971-80	1981-90	1991-00	2001-10	2011-16
P (mm)	82.9	57.7	63.3	38.6	51.8
2 T (°C)	53.0	53.8	54.0	54.5	54.7

Source: Data from SODEXAM

The average contributions to total annual rainfall remain naturally higher for rainy seasons than for dry seasons (Table 14). But over the decades, this contribution decreases to -10% and more for the long rainy season in favour of the short rainy season and the long dry season. These variations are more marked from the decade 2000 onwards.

Table 14: Average percentage contributions to Fresco's annual rainfall for the different seasons

Season	Long rainy season	Short rainy season	Long dry season	Short dry season
Period				
1971-80	74.9	14.3	6.5	4.3
1981-90	71.6	15.7	6.2	6.5
1991-00	72.1	17.2	6.9	3.8
2001-10	67.4	15.3	11.9	5.4
2011-17	61.3	24.7	9.9	4.2

Source: Data from SODEXAM

For the stabilization (4.5) and pessimistic (8.5) scenarios, projections do not show a significant trend in rainfall at Fresco by 2100; rainfall can be expected to be almost equal (RCP 4.5) or even lower (RCP8.5) than the current situation. Figures 15 and 16 show the rainfall level projections for scenario 4.5 and scenario 8.5 respectively.

Figure 15: Overall projections of precipitation trends at Fresco according to scenario 4.5 from the global CMIP5 model

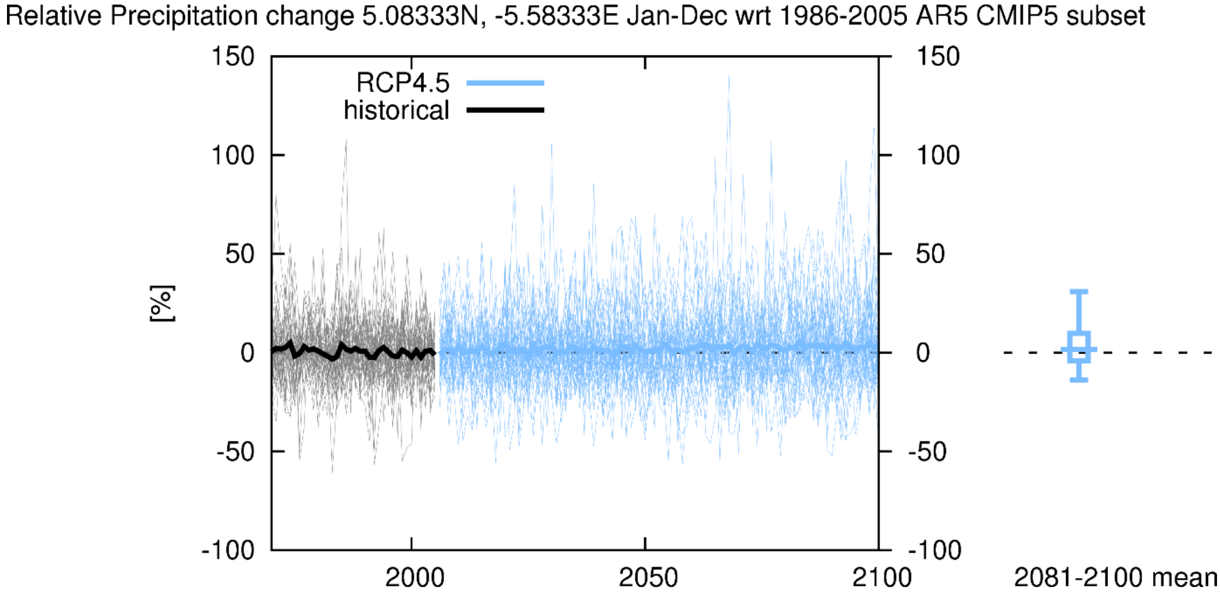
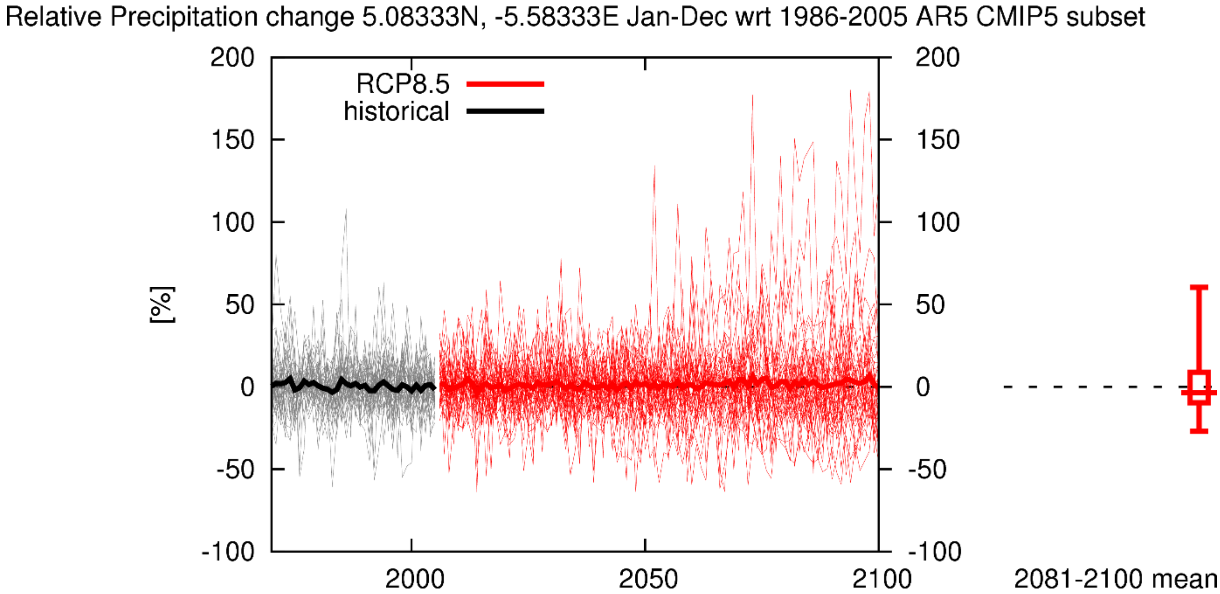


Figure 16: Overall projections of precipitation trends at Fresco according to scenario 8.5 from the global CMIP5 model

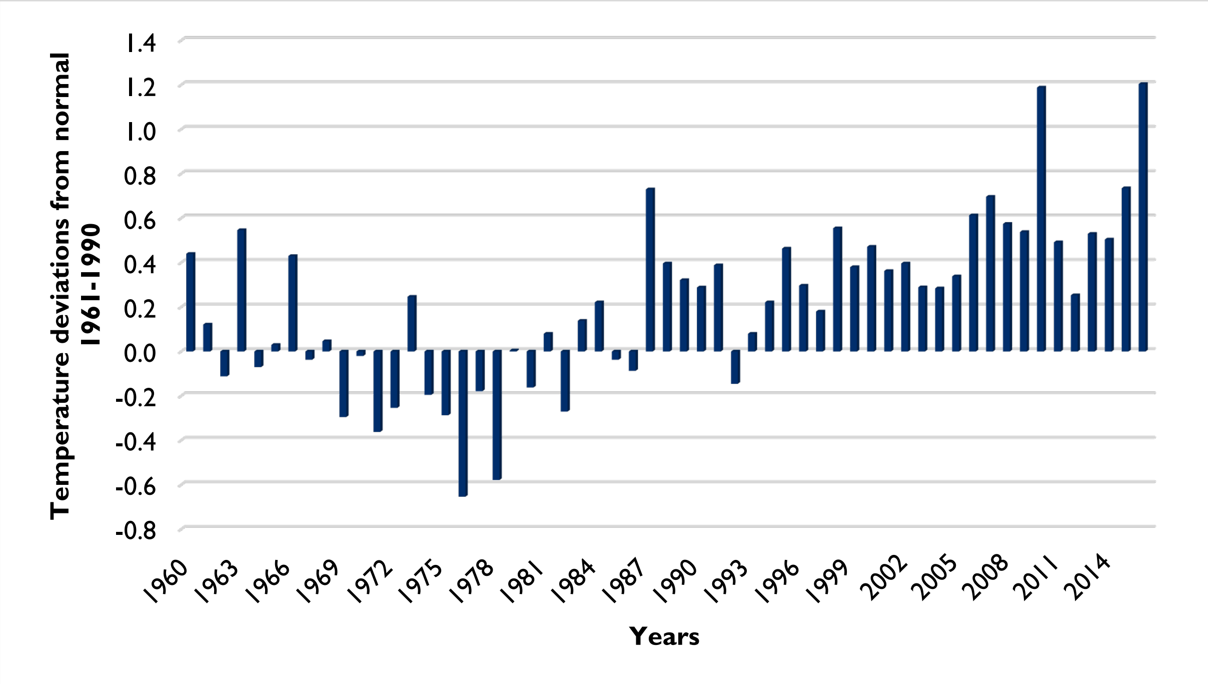


4.1.1.2 Temperature

Analysis of the trend in average annual temperatures since 1961 shows that there is significant annual variability between the various years. Nevertheless, if we analyze the trend over 50 years, we observe an increase in the percentage of days when the maximum temperature is above the 90th percentile (TX ≥ 90th percentile), hence marking an increase in hot days. The trend is 0.6 °C. This is a sign of this effective warming of the atmosphere in the Gboklè region. This warming has been significant since the late 80s, when the average annual temperature did not fall below the 1961-1990 normal (Figure 17).

The analysis of the ten-year gaps shows a gradual warming in the Gboklè over the last thirty years (Table 15). As a matter of fact, the 1961-1970 decade experienced an insignificant warming of 0.1°C and the 1971-1980 decade a slight cooling of 0.2°C. Over the last 3 decades, temperatures have increased by 0.2°C between 1981 and 1990, by 0.3°C between 1991 and 2000 and by 0.5°C between 2001 and 2010.

Figure 17: Annual temperature anomalies to normal 1961-1990 at Sassandra



Source: Data from SODEXAM

Table 15: Ten-year average temperatures from 1961 to 2010 and normalized deviations at Sassandra

Decade	Average Temprrature (°C)	Deviations from 1961-1990 normal (°C)
Average 1961-1990	25.5	0
1961-1970	25.6	0.1
1971-1980	25.3	-0.2
1981-1990	25.7	0.2
1991-2000	25.8	0.3
2001-2010	26.1	0.5

Source: Data from SODEXAM

The projected temperature variation trends are in line with the trends observed over the period of 1961-1990, i.e. the differences remain positive, regardless of the scenario. However, for scenario 4.5 (Figure 18), warming remains below 2.0°C over the period 2006-2010, while for scenario 8.5 (Figure 19), warming reaches 4.0°C.

Figure 18: Overall projections of annual temperature changes at Fresco according to scenario 4.5 from the CMIP5 global model

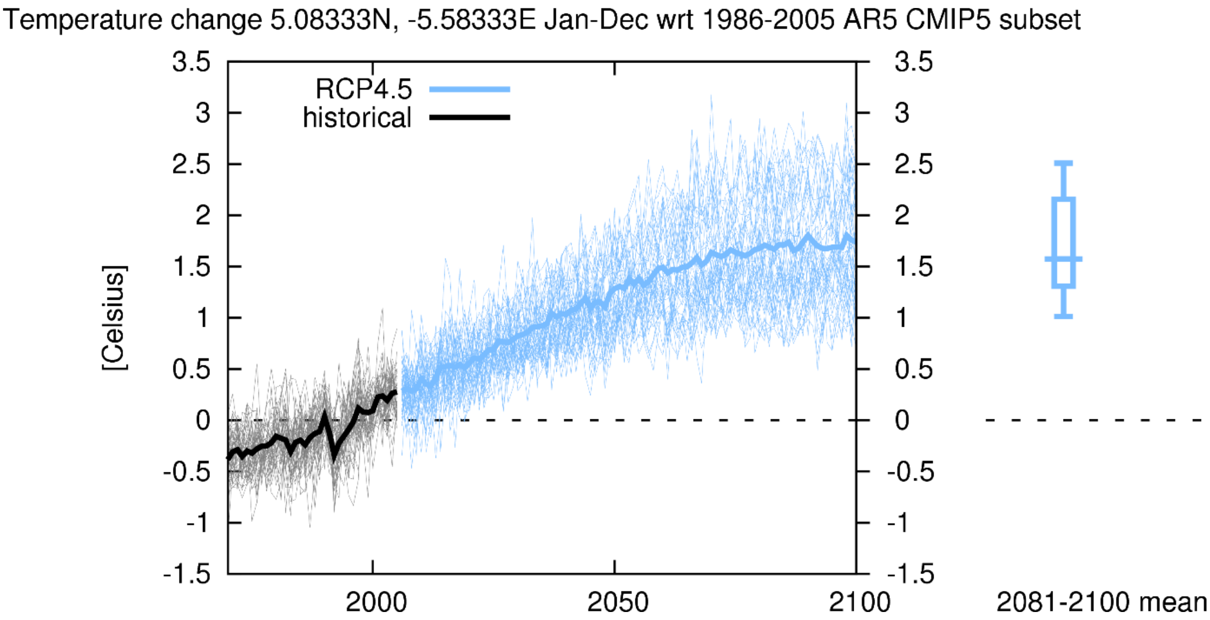
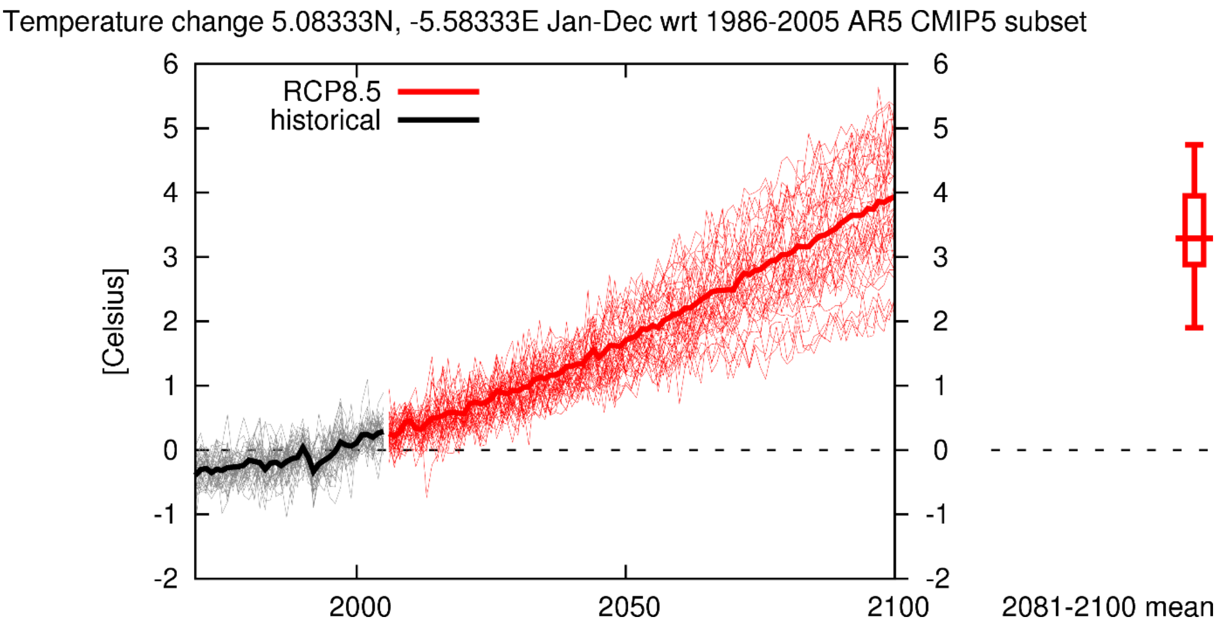


Figure 19: Overall projection of annual temperature trends at Fresco according to scenario 8.5 from the global CMIP5 model



In summary, depending on the scenarios (Figures 18 and 19), the relative warming range on Fresco ranges from +1.0°C to +2.0°C for the 2050 horizon and from 1.5°C to 4.0°C from 2050 to the end of the 21st century.

4.1.1.3 Extreme Events

Several cases of flooding have been observed, with significant changes in frequency over the past three decades, according to official reports communicated by the national press. There has been an increase in the frequency of extreme floods over the past 10 years (July 2014 and June 2017 when the "Coastal" area was flooded by rainwater from the national road). These natural disasters are major issues in

Fresco with the current and potential impacts of climate change on the frequency of extreme events and the resulting damage.

Episodes of moderate to severe dry spells are increasingly observed by SODEXAM (2014). Marine flooding due to storms and gales occurring between April and July. All these factors have therefore increased the impact of natural forces and made the Fresco coastal area a sensitive area increasingly affected by sea-level rise

According to the IPCC's 5th Assessment Report, global mean sea level rose by 19 cm over the period of 1901-2010. Global warming that raises sea levels is threatening coastal cities and populations. A sea level rise of 5 to 10 cm will double the frequency of flooding in the tropics between 2030 and 2050. Every year, sea levels around the world rise by 3 to 4 mm. but this could accelerate due to global warming and melting ice. By 2100, the increase should reach between 30 cm and one metre or more. This trend stimulates flooding during high tides, increases coastal erosion, changes wave dynamics and increases the risk of flooding. The rise expected to occur between 2030 and 2050 will double the risk of flooding in coastal cities in tropical regions such as Fresco in Côte d'Ivoire. This will have an impact on the economy of coastal cities that are particularly vulnerable to flooding during storms.

These sea level changes will have a direct impact on the coastline of the Fresco region, with multiple consequences on economic activity, natural environments and related infrastructure.

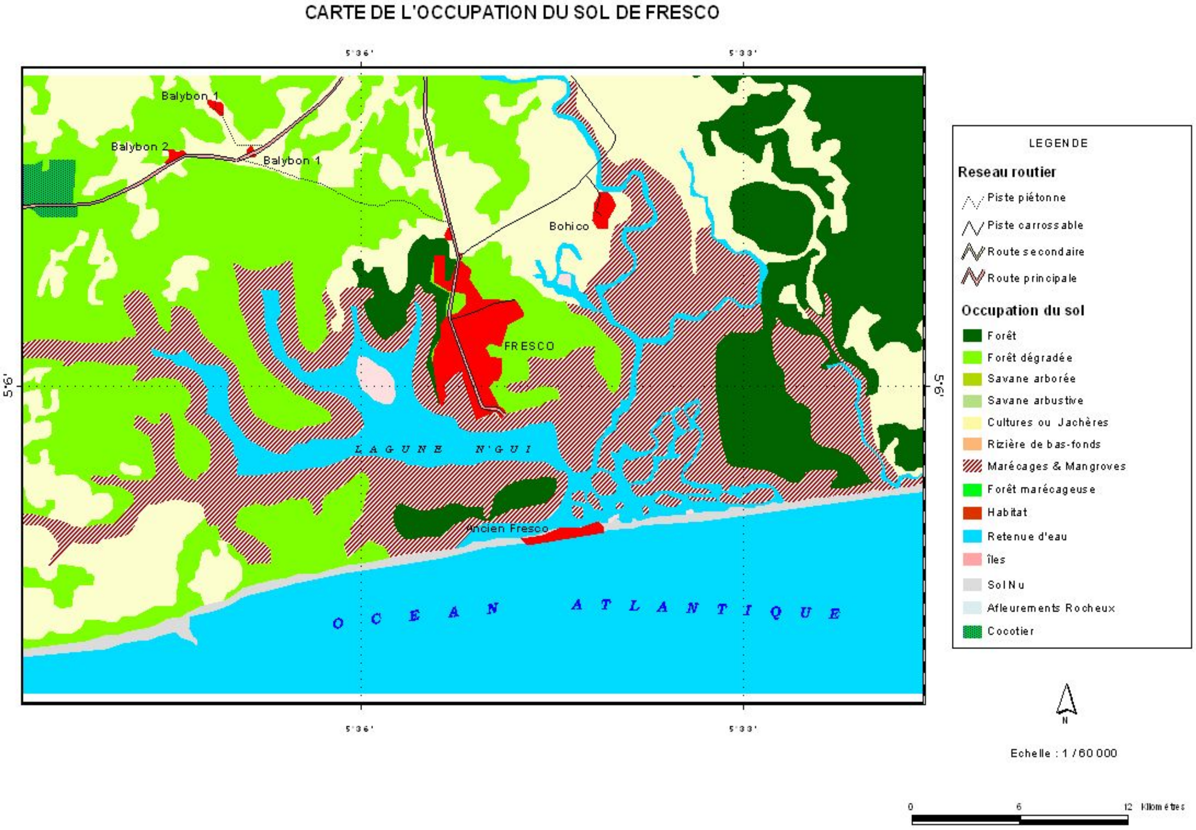
4.1.2 SURFACE STATE CHANGES OF MANGROVES AND OTHER ECOSYSTEMS IN THE FRESCO LAGOON LANDSCAPE

4.1.2.1 Mangroves

According to Egnankou, 1989. The area between Sassandra and Grand-Lahou bordering Fresco is rich in natural resources. This area, a true biodiversity hotspot, is under various pressures. This observation was also made by Soro et al (2014), who highlighted the importance of the forests in this part of the Ivorian coast. Blasco, in 1983, has already pointed out that mangrove ecosystems and other wetlands play an essential role in the development of biodiversity. Mangroves represent a breeding ground for many aquatic animal species. Transit sites for migratory species and habitats for many terrestrial species. For certain animal species in continental or marine waters, residence in the mangrove at certain stages of their development cycle is mandatory. Despite the important role attributed to them, mangrove ecosystems suffer, like all other ecosystems, from human destructive actions and the adverse effects of climate change (McLeod and Rodney. 2006).

For nearly 30 years, Fresco's mangroves have been steadily decreasing to reach its very low level today. The pre-1980 baseline situation of ecosystems in the Fresco lagoon landscape is represented by the following land use map, where vegetation degradation could be estimated at about 10% (Figure 20). The 1991 study by Egnankou of the SPOT satellite image in colour composition of scenes 48/340 and 49/340 from March and December 1988 on the Fresco lagoon landscape (scale 1/83,000) produced a map showing an estimated vegetation degradation status of about 40% east of the Gogbey lagoon, 30% south of the lagoon and only 20% southwest and west.

Figure 20: The Fresco lagoon complex and the surrounding forests



Egnankou. 1991

In 1989, observations made to determine the state of mangrove degradation gave estimates of about 50% in the east and south of Gogbey Lagoon (Figure 21). The degradation rates in the southwest and west had remained unchanged at about 20%.

Figure 21: Anarchic exploitation of R. racemosa wood in the south of the Gogbey lagoon (1989)

Table 16 presents the Summary of Results on the Degradation Status of Mangroves in the Fresco Lagoon Landscape in February 2018 and describes the details of the nineteen (19) stations and fifteen (15) transects that were studied (please note that Table 16 also includes Figures 22-28). The mangrove ecosystem is 60-70% degraded compared to its 1984 level.

Due to the morphology of the coastline with rugged topographical relief to the west of the lagoon (cliffside) and a sandy barrier beach to the east, the ecosystems face atmospheric phenomena on the coastline in different ways. These are lagoon mangroves bordering the Gogbey lagoon and estuary mangroves that occur on the banks of the coastal rivers: Bolo and Niouniourou and the Gnu rivers. The nature of mangroves that are estuarine and lagoon-like makes them more vulnerable to heavy flooding with prolonged immersion of plants. The lagoon landscape of Fresco is the only one in Côte d'Ivoire to contain these two types of mangroves in the country. They are places of "nurseries" for many aquatic animal species, transit sites for migratory species and habitats for many terrestrial species. Extreme events with high frequency and intensity have impact on mangroves that are already fragile and affected by human overexploitation and, consequently, the entire value chain that depends on them. Moreover, human activities regarding wood logging observed in the field in February 2018 (see photo gallery n°3) and the dead tree trunks that littered the fields in some parts of the mangrove, are all proves of current devastating nature of the mangroves.

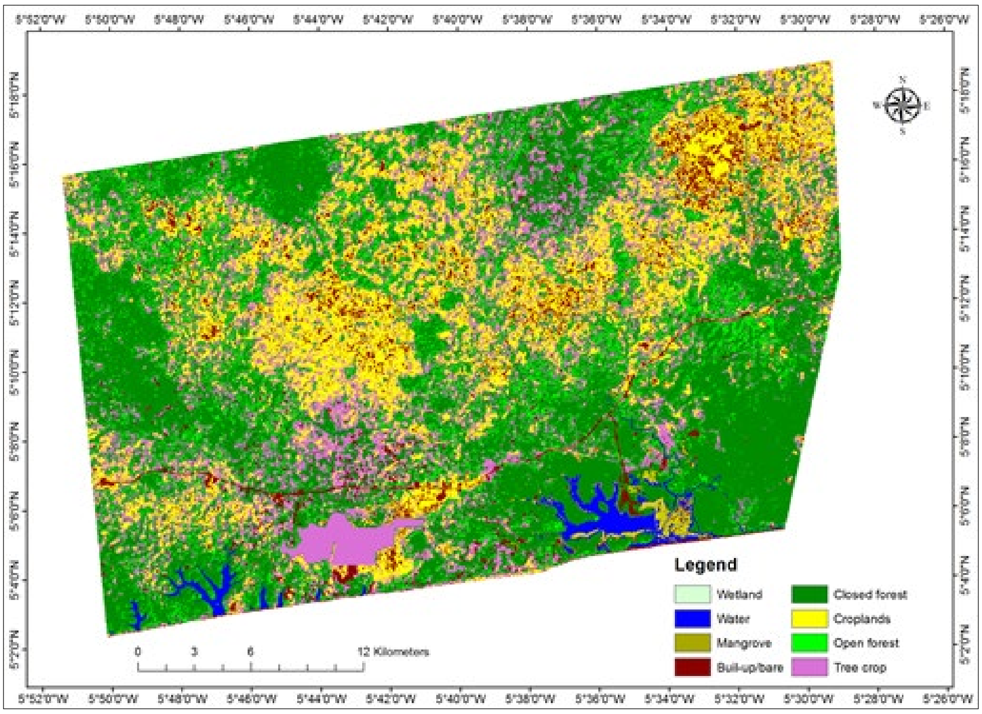
Photo Gallery n° 3: Views of the mangrove in the Fresco lagoon landscape as of February 2018

Sedimentation remains very strong under mangroves. This is a general observation that has been confirmed in the Fresco mangroves. Indeed, through the morphological structure of mangroves with aerial roots, the mangrove root system acts as an inextricable network (meshes) that traps sediments and participates in the creation of "new lands". This is what allows the mangrove to fight against bank erosion. Concerning the regeneration potential, observations show that Fresco mangroves have a high regeneration potential. By February 2018, most of the trees were bearing many fruit and some had already developed propagules (seedlings) that, at maturity, can constitute a huge reservoir of plans for the reclamation of bare spaces or spaces created by sedimentation. The only obstacle to this regeneration process is the closure of the pass.

4.1.2.2 Other Coastal Forests

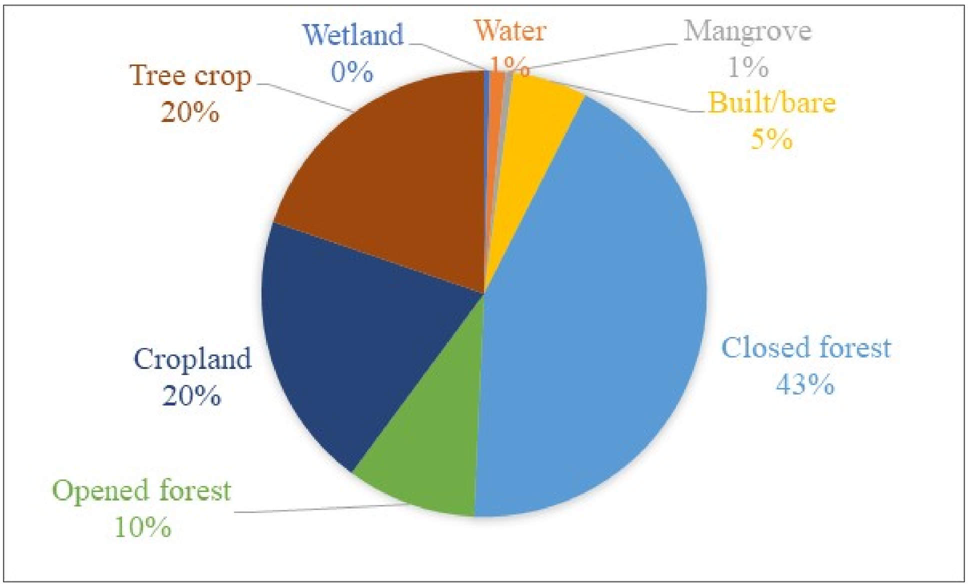
Mapping of changes in land use and occupancy shows that in 1990 (Figures 29 and 30) forests represented about 43% (419 km²) of the Fresco lagoon landscape. Cash crops remain the second largest land use category (195 km². 20%); slightly less than half of the forests. In some places (especially in the north), forests are associated with plantations. These are generally located near road networks, especially in Zuzuoko and Daliziele in the south. Moreover, near Daliziele, we mainly find coconut plantations.

Figure 29: Land use and occupancy mapping in 1990 of the Fresco lagoon landscape



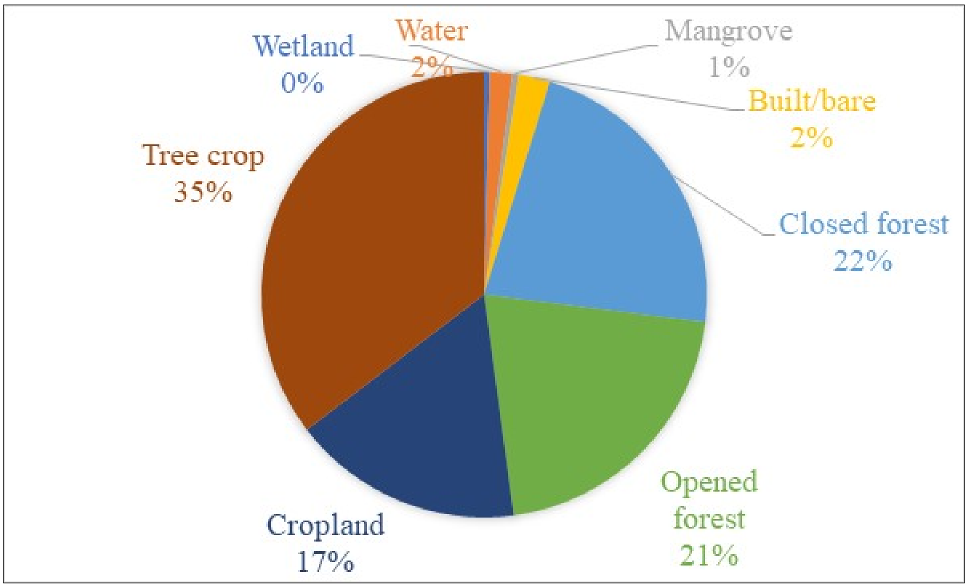
Open forest made up about 9% of Fresco's lagoon landscape in 1990 (Figure 30). This represents an area of 192 km². Water bodies form about 1.1% (10.9 km²) of the total area and are found mainly along the Gulf of Guinea coast in the form of rivers, lagoons and estuaries. Mangroves (5.6 km², 0.6% Figure 31) and wetlands (4 km², 0.4%) are the second smallest and least important coverage in the landscape respectively.

Figure 30: Distribution in % of the different land use and occupancy categories in 1990



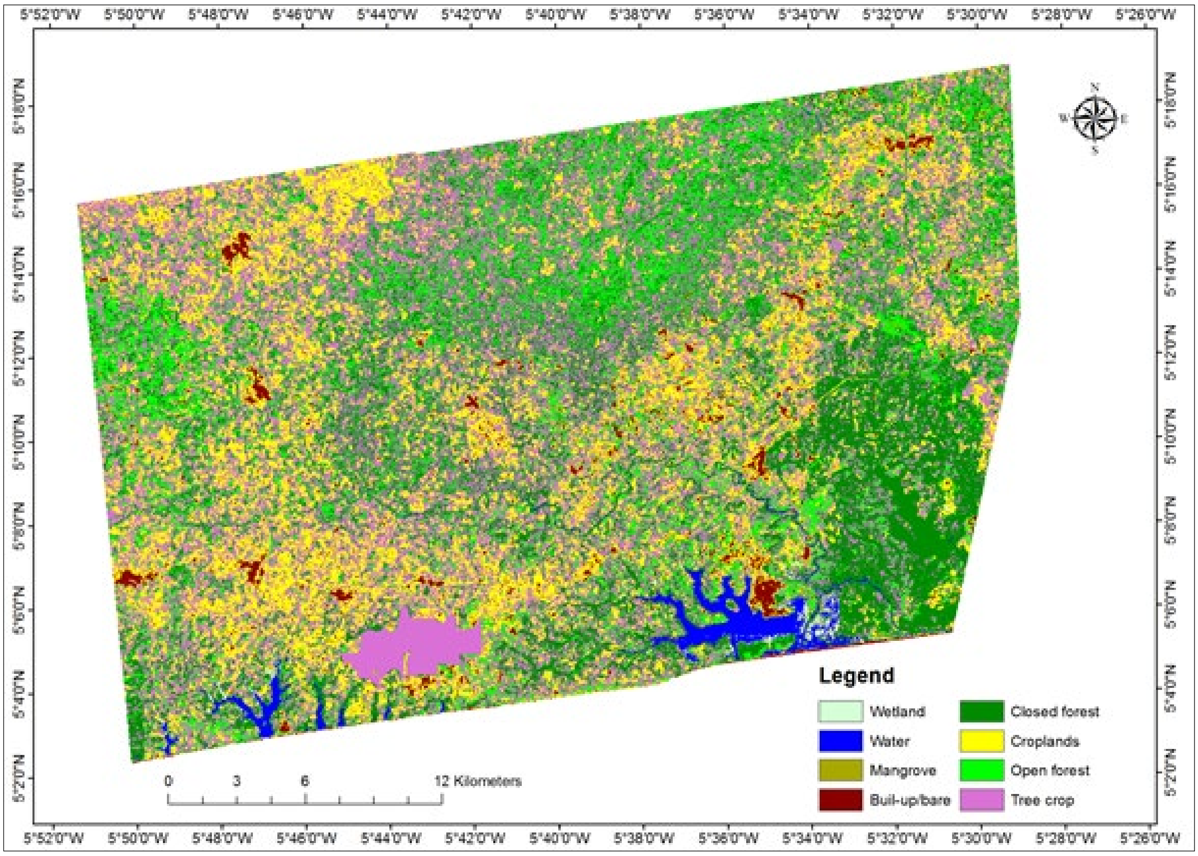
In 2017 (Figure 31), land use and occupancy mapping shows that plantations are now the highest cover (343 km²), 35.37%. Next comes dense forest (216 km², 22.2%), open forest (202.9 km², 20.9%), cultivated land (163 km², 16.8%), built areas (22.1 km², 2.28%' %), water (16 km²), mangroves (4.3 km², 0.45%) and wetlands (3.7 km², 0.39%).

Figure 31: Distribution in % of the different land use and occupancy categories in 2017



In the Fresco lagoon landscape, the dominant land use and occupancy category is now plantations; and when you move north, the density of plantations increases considerably (Figure 32). Moreover, in Okoumodrou, according to the populations, "*the disappearance of the forest to the detriment of plantations has exposed cocoa plantations to solar radiation; we are no more witnessing the agro-forestry that protected young cocoa plants*". In the southwest near estuaries, and more precisely in the localities of Kosso, Zuzuoko and Daliziele, coconut is the common cash crop plantation (Figure 32). The forest that is still almost "closed" or even protected is in Fresco and looks virgin because it is on wetlands. And accessibility to this part of the area is somewhat difficult due to its topographical relief.

Figure 32: Land use and occupancy mapping in 2017 in the Fresco lagoon landscape



As illustrated in Figures 33 and 34, many changes have taken place in the Fresco landscape. Wetlands, mangroves and forests are sidetracked for the benefit of commercial plantations. But these changes must be linked to population growth, the arrival of migrants who settle for farming purposes. It is even reported in some places that people settled in forest reserves. As a result, the number of pressure and disappearance of forests are increasing. (tables 17a and 17b).

Figure 33: Changes in area within the same occupancy and land use category between 1990 and 2017

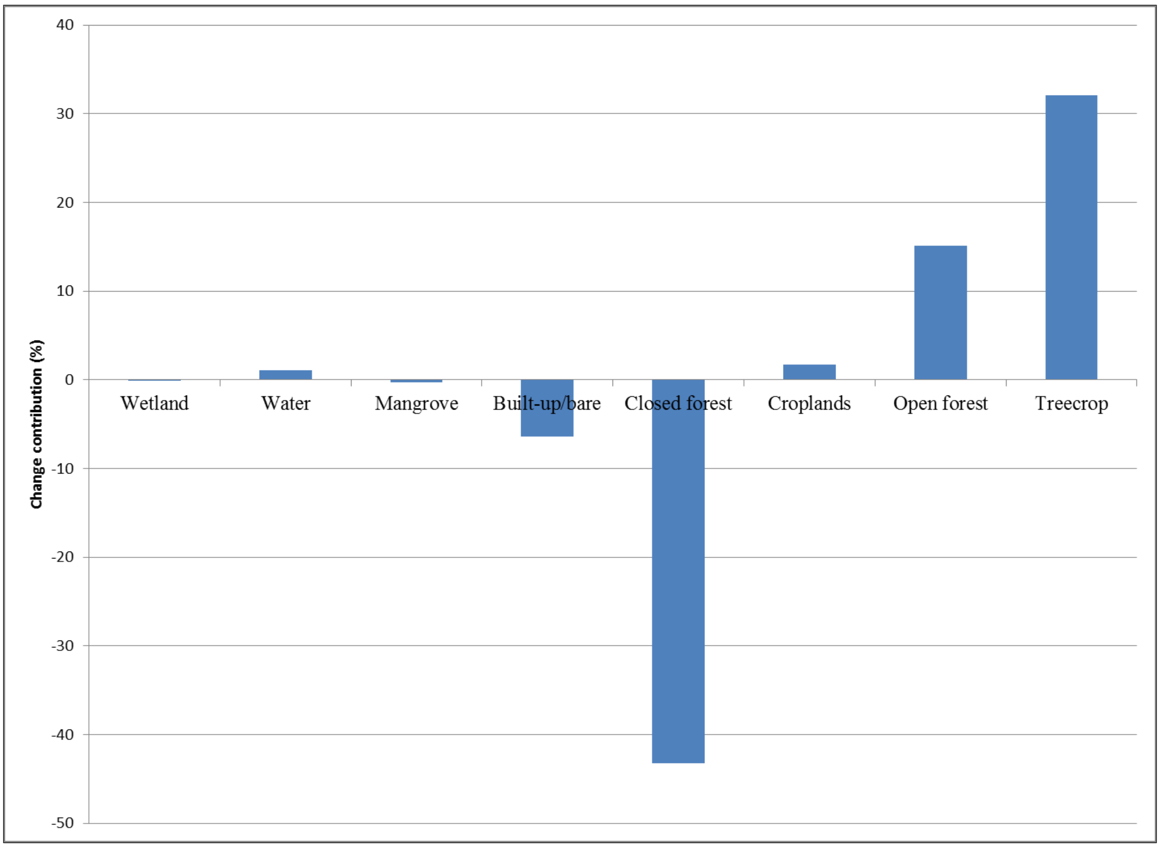


Figure 34: Distribution of changes in the Fresco lagoon landscape

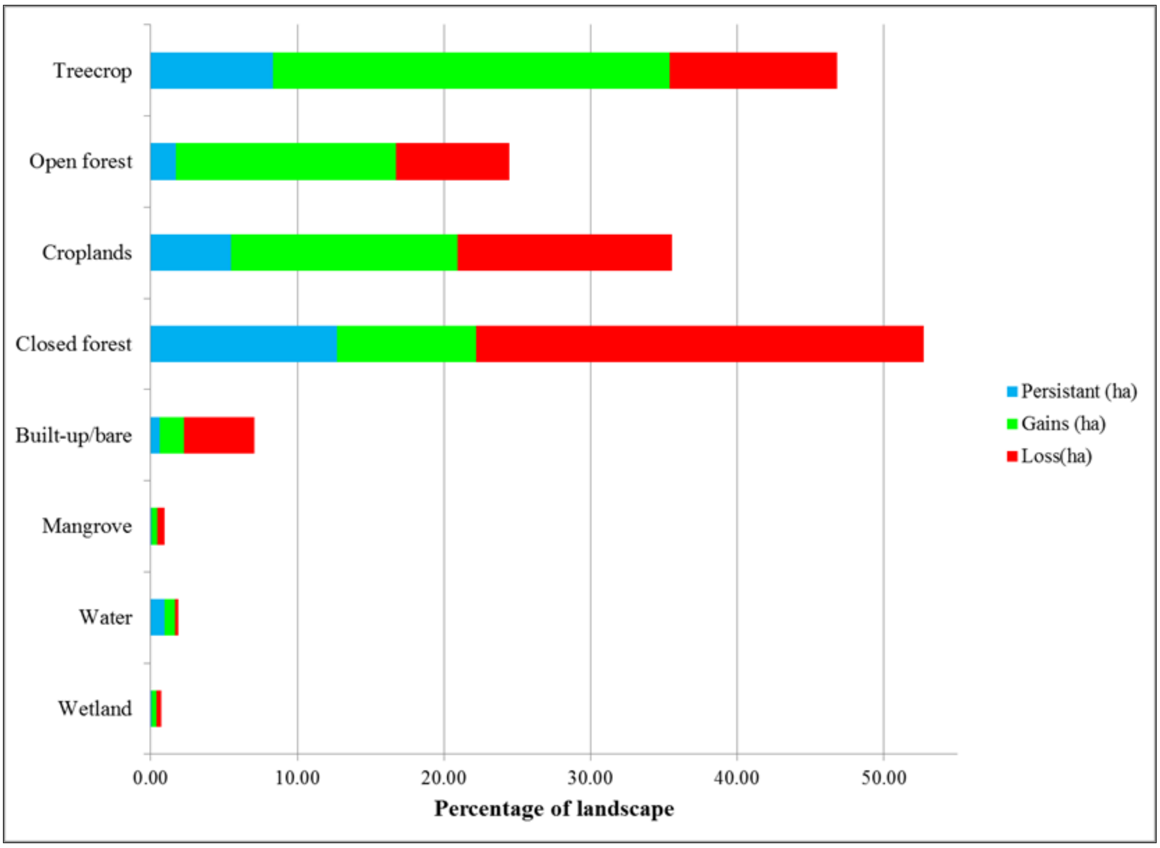


Table 17a: Percentages and changes (negative percentages represent a reduction)

Classes	1990 Total area (km^2)	1990 % Area	2017 Total area (km^2)	2017 % Area	% change
Wetland	3.9996	0.41%	3.7386	0.39%	-6.53%
Water	10.8567	1.12%	16.038	1.65%	47.72%
Mangrove	5.6304	0.58%	4.3785	0.45%	-22.23%
Built-Up/Bare	52.326	5.39%	22.1148	2.28%	-57.74%
Closed Forest	419.4459	43.22%	215.5248	22.21%	-48.62%
Opened Forest	91.4274	9.42%	202.86	20.90%	121.88%
Cropland	194.7762	20.07%	162.5139	16.75%	-16.56%
Tree Crop	191.9466	19.78%	343.2402	35.37%	78.82%

Table 17b: Percentages and changes by survey area

	0 to 10km		11 to 20km		>20km	
	1990	2017	1990	2017	1990	2017
Wetlands	240.84	**282.69**	36.45	**9.9**	122.67	**81.27**
Water	859.05	1208.88	38.52	107.01	188.1	287.91
Mangroves	551.07	**304.56**	6.75	55.53	5.22	77.76
Built/bare	941.4	751.59	3147.66	801	1142.91	658.62
Close forests	13829.76	**7691.76**	13140.36	**9007.47**	14972.85	**4851.45**
open forests	2134.71	**2884.23**	3334.32	**7774.56**	3672.99	**5590.89**
Plantations	2828.07	**6128.46**	10601.01	**16064.91**	5764.05	**12130.38**
Foodcrops	1984.59	**4117.32**	11642.13	**8126.82**	5851.17	**8041.68**

The main dynamic of change concerns the forest which has been converted into agricultural land, with a predominance of cash crops plantations. According to Ehuitché (2015), farmers contribute significantly to deforestation in Côte d'Ivoire. Due to population growth and poverty, the rural poor use forests to quickly find a solution to their economic hardships. Côte d'Ivoire is the world's largest cocoa producer. But this has led to deforestation; now the forest is in the form of "small, fragmented forest islands" (Bitty et al. 2015). Coffee, oil palm, rubber and coconut trees are among the plantation crops that are found in the Fresco landscape. In addition, the transformation of landscapes into plantations has not only improved household incomes, but has also had an environmental consequence, with not only negative effects on the natural capital, but also on the social and human capital of local communities at varying degrees (van Vliet et al. 2012).

In southern Côte d'Ivoire, activities such as unregulated sand winning and coastal deforestation of mangroves are causing some changes. Mangroves are seriously decreasing (Abe et al. 2000). Deforested mangroves are over-exploited for traditional uses such as construction, firewood, etc. Such unsustainable use of resources significantly reduces the ability to support the basic socio-economic needs of rural populations. Mangroves provide habitat for fisheries resources that are essential for fishing and are the main source of livelihood for coastal dwellers. The destruction of mangroves reduces future income, thereby contributes to planned and easy destruction of coastal communities, thus threatening the natural, socio-economic and physical vulnerabilities of communities (Antwi et al. 2015). Deforestation leads to the loss of nutrients in plants and soil, increases soil erosion and reduces soil productivity and in turn reduces agricultural yields; resulting in malnutrition (UNEP. 2013). The increase in deforestation and soil erosion pushes farmers to seek new land for agriculture, and sometimes they are forced to exploit less suitable areas (Ehuitché. 2015). This weakens at the same time these landscapes where the agricultural front is advancing rapidly and this is how balance disruption, that are harmful to the environment, comes about.

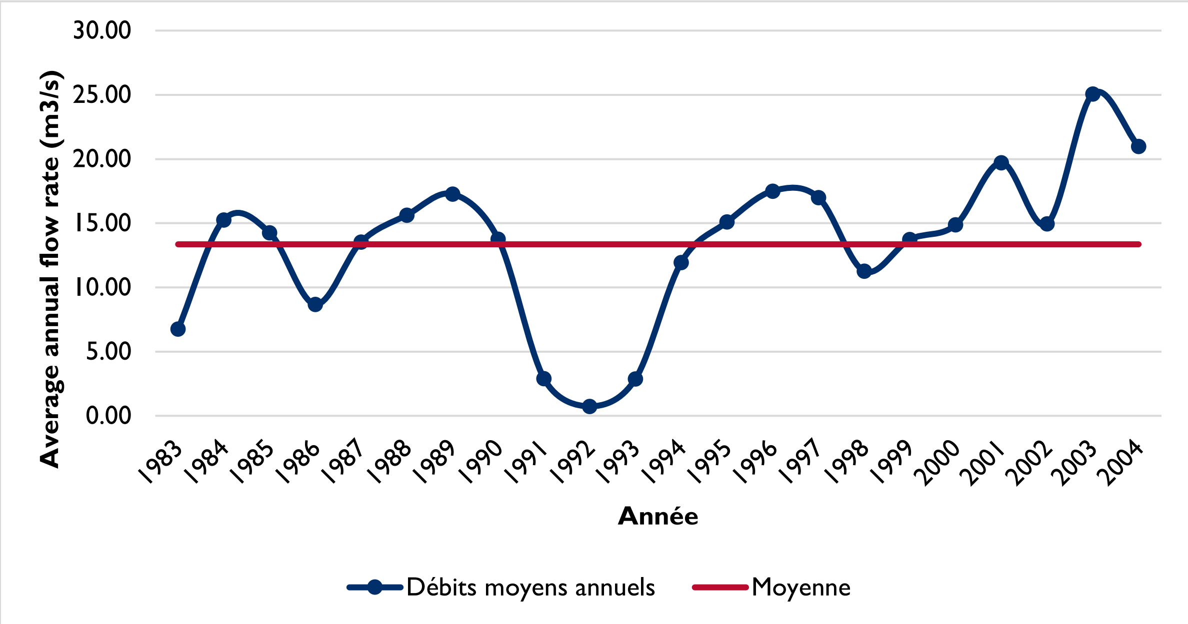
4.1.2.3 Water Resources

The interannual fluctuation of the annual modules of Niouniourou in Dahiri is significant from 1983 to 2004 around an average value of 13.36 m3/s with a coefficient of variation of 0.45 (Figure 35). The flows are very low in 1991, 1992 and 1993 with 2.91; 0.74 and 2.88 m^3/s respectively.

A very large number of zero daily average flows were observed during these three years. Therefore, the 90s is in deficit compared to the previous decade in terms of flow rates. But thereafter, flows increased overall from 1994 to 2004 and remained above 14 m3/s after 2000.

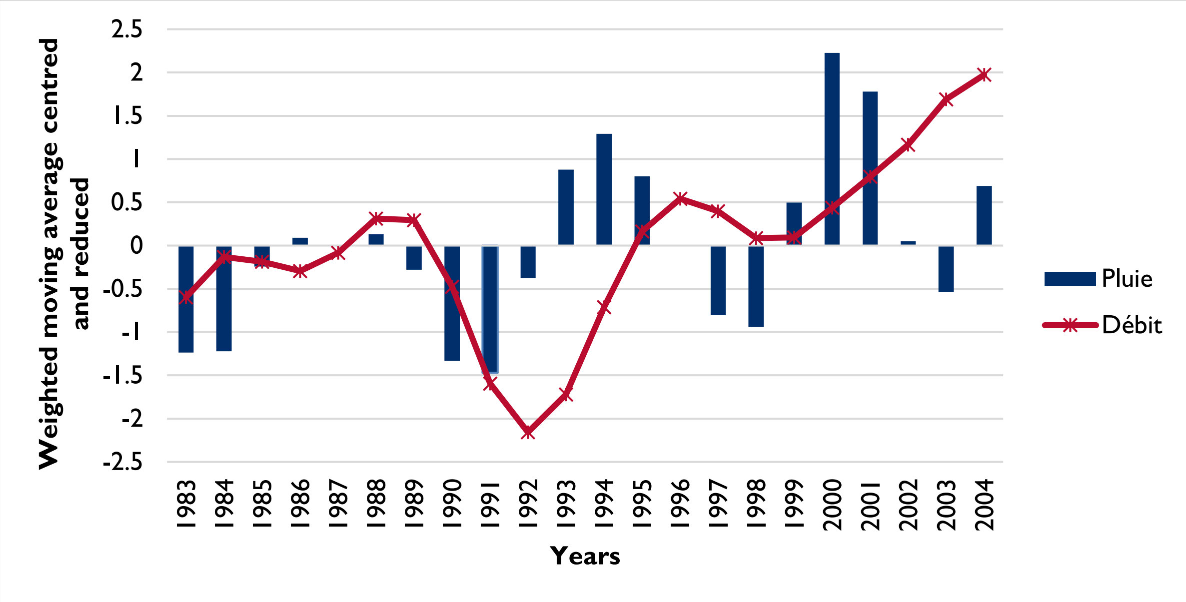
The trend in flows clearly follows that of rainfall, but often with lags of one year or more (Figure 36). The strong downward trend in flows from 1990 to 1992 is preceded by that of rainfall from 1989 to 1991. When rainfall begins to increase thereafter in 1992, flows follow slightly in 1993 and more clearly in 1994 after the rain in 1993. Rainfall and flows thus have an overall upward trend from 1994 to 2004. The average annual mean flows over the periods 1983-1993 and 1994-2004 are 10.15 and 16.56 m3/s respectively. Flow rates increased by 63% over the period 1994-2004.

Figure 35: Interannual fluctuation of the annual modules of Niouniourou in Dahiri over the period of 1983-2004



Source: Data from the Directorate of Hydrology, Standards and Quality

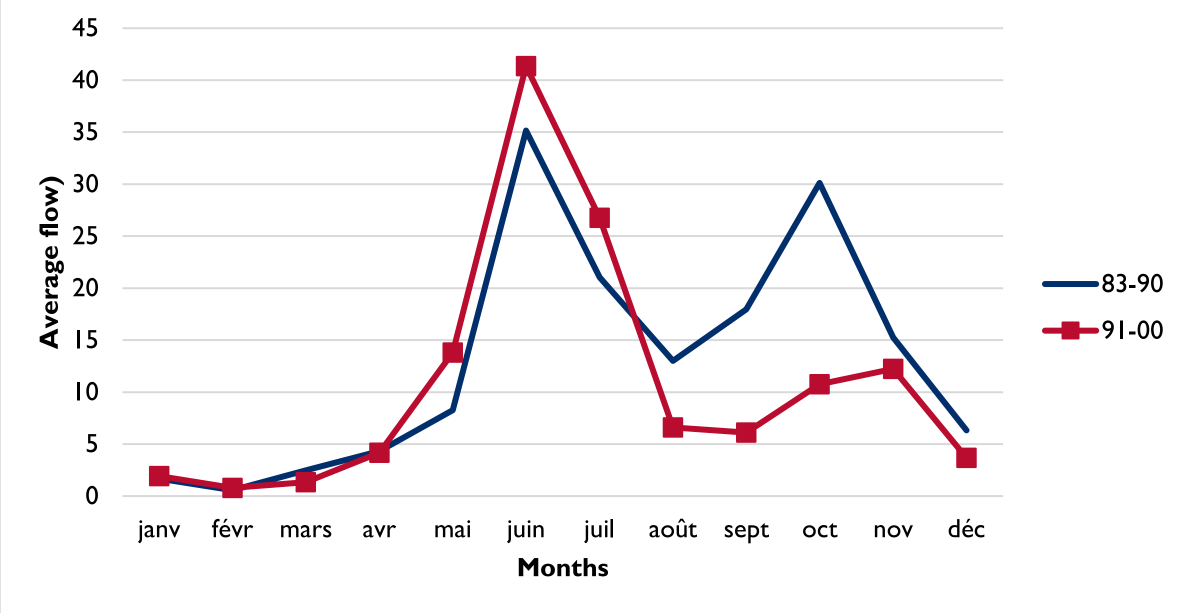
Figure 36: Comparative trends in annual rainfall at Fresco and average annual Niouniourou flows at Dahiri over the period 1983-2004



Source: Data from the Directorate of Hydrology, Standards and Quality

The hydrological regime is of the equatorial transition type, which is fairly closely modelled on the rainfall regime (Figure 37). It is characterized by two periods of high water corresponding approximately to the two rainy seasons and two periods of low water resulting from the dry seasons. The notable trends in the evolution of the hydrological regime over different periods are variable average flows from the peak of the first high water period, but always occurring in June. For the second-high water period, the peak tends appears more in October than in November with an increase in flows during the second-high water period. The first period of low water seems to be limited to August alone since the flow increases in September. The latter two trends seem to be the result of the increase in rainfall during the short rainy season and the long dry season at the expense of the long rainy season. The average flows in October and November (second-high water period) are higher over the period 2001-2004 with 39.73 and 33.50 m3/s respectively. The same applies to March and April. Thus, the contribution of the first high water period to the annual module decreases by more than 20% and that of the second-high water period increases at the same time by more than 20% (Table 18).

Figure 37: Variations in average monthly flows per decade from Niouniourou to Dahiri



Source: Data from the Directorate of Hydrology, Standards and Quality

Table 18: Average percentage contributions to the annual module of Niouniourou for the different seasons

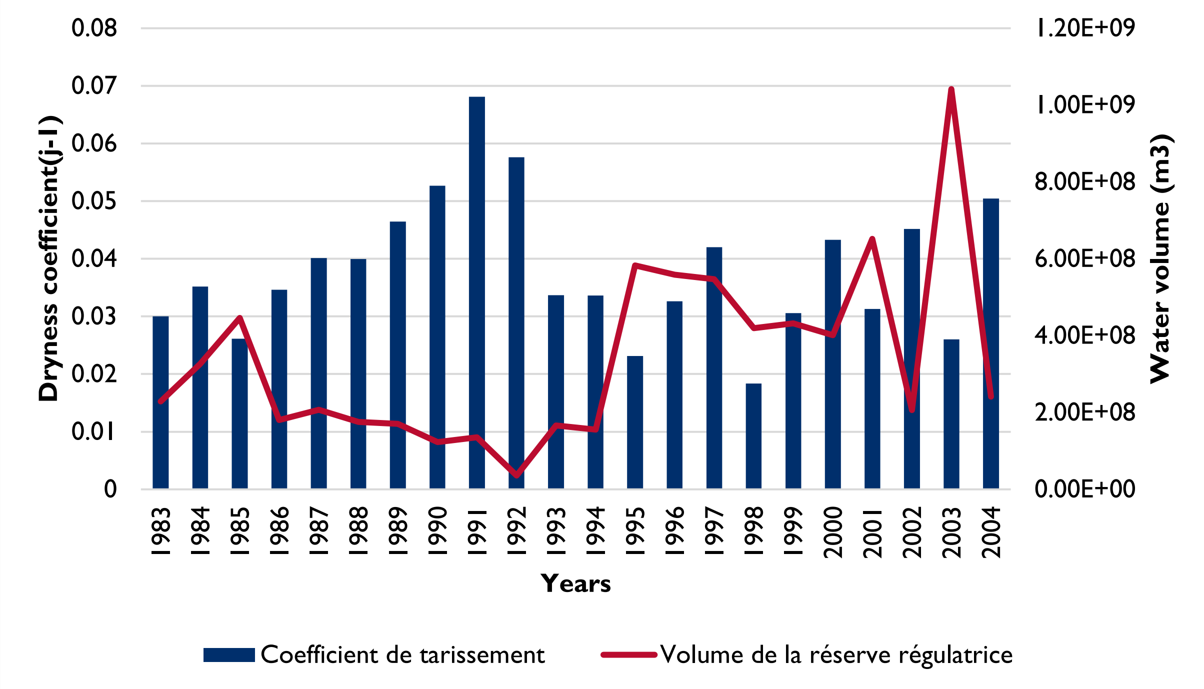
Season	Long rainy season	Short rainy season	Long dry season	Short dry season
Period				
1983-90	44.05	29.05	7.07	19.83
1991-00	66.47	17.74	5.98	9.81
2001-04	47.45	30.23	9.63	12.68

Source: Data from SODEXAM

Rainfall fluctuations in Fresco affect river flows on an annual and monthly basis. The average annual flows are therefore decreasing over the period of 1983-2004. However, they increased by 63% over the period 1994-2004 compared to the period 1983-1993. In response to an increase in rainfall during the short rainy season, monthly flows become higher during the second-high water period.

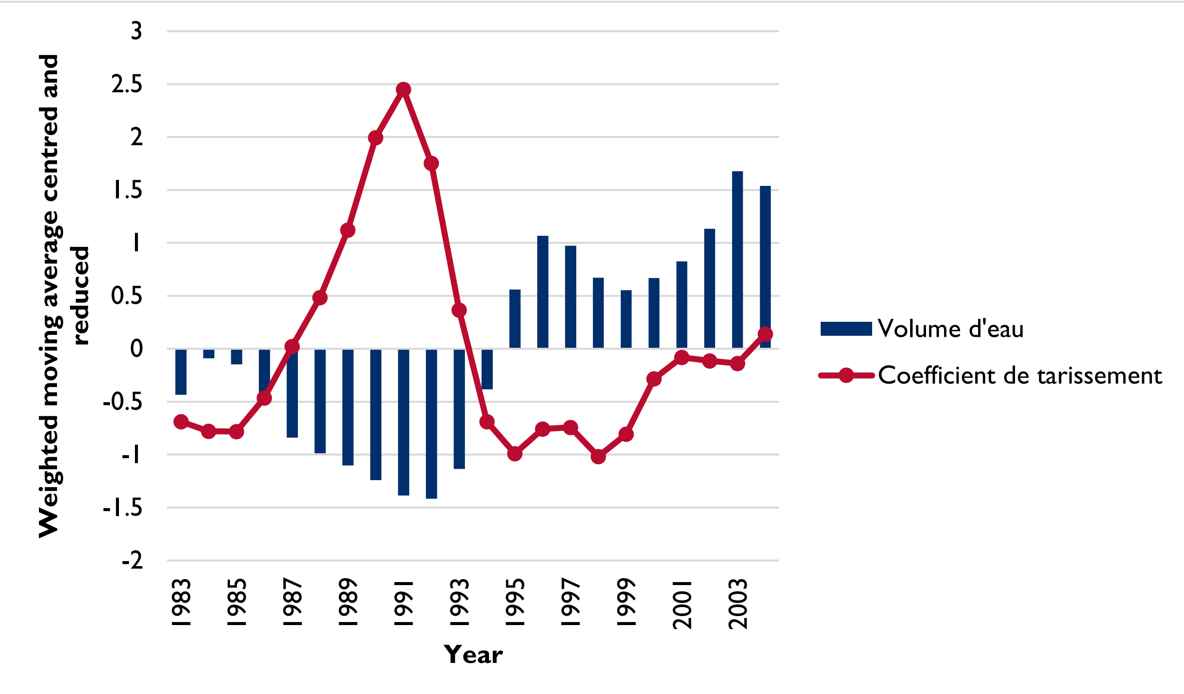
The drying coefficient is proportional to the rate of emptying of the slick. It increases during periods of drought and decreases when the groundwater is recharged. The drying coefficients and water volumes of the regulatory reserve have an inverse evolution (Figures 38 and 39). Overall, the drying coefficients are high over the period 1983-1994 and fall over the period 1995-2004 with averages of 0.042 and 0.034 d-1 respectively, i.e. a variation of -17%. It is the opposite trend for the volume of the regulatory reserve that feeds the decline. This volume increases from 1.96 108 to 5.08 108 m^3, an average difference of +159%. Both groundwater and surface water resources follow variations in rainfall, but with at least one-year lag (Figure 40).

Figure 38: Variations in the drying coefficient and water volume of the hydrogeological reserve likely to supply the Niouniourou surface runoff in Dahiri data sauce



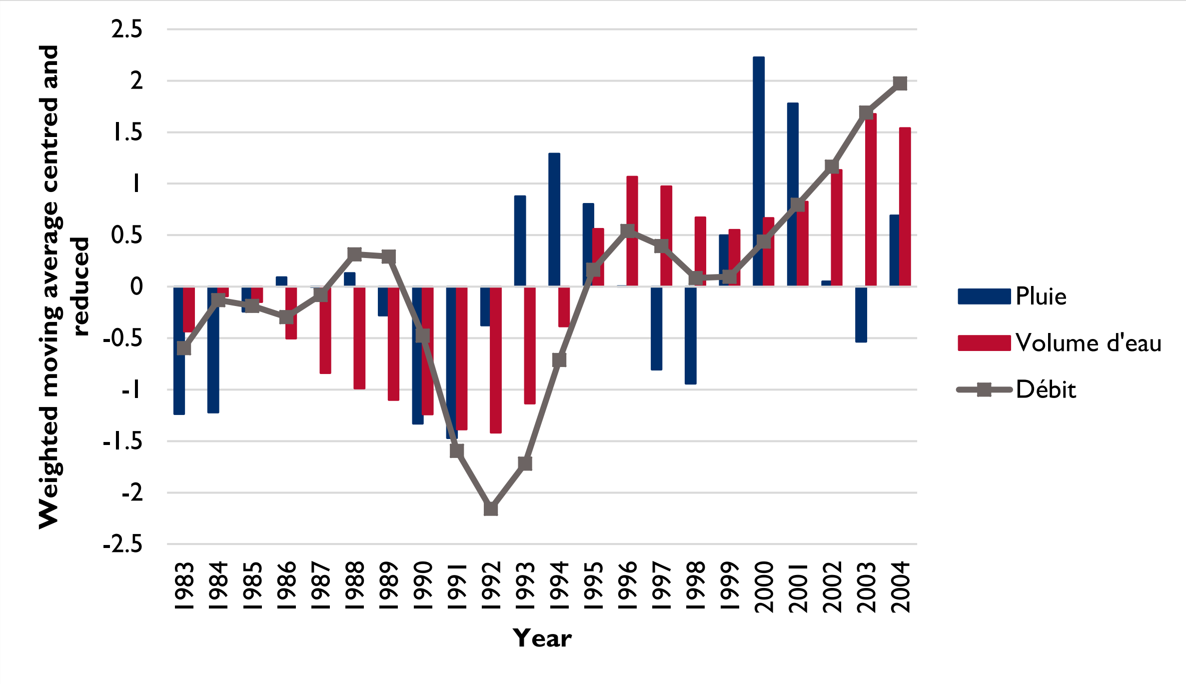
Source: Data from the Directorate of Hydrology, Standards and Quality

Figure 39: trend over the period 1983-2004 of the drying coefficients and water volumes mobilized by the aquifers of the Niouniourou basin in Dahiri



Source: Data from the Directorate of Hydrology, Standards and Quality

Figure 40: Trends in rainfall, surface flows and groundwater volumes over the period 1983-2004



Source: Data from the Directorate of Hydrology, Standards and Quality

The behaviour of groundwater resources during variations in rainfall and river flows is assessed by those of the drying coefficient and volume of water mobilized by the regulatory reserves. With lags of at least one year, these two parameters show that underground resources are influenced by variations in rainfall and flow. Thus, the drying coefficients are high over the period 1983-1994 and decrease over the period 1995-2004. The volumes of water mobilized by aquifers have a reverse evolution over these periods. They show average deviations of -17% and +159% respectively over the period 1995-2004 compared to the period 1983-1994.

The calibration of the GR2M model is very satisfactory over the period of January 1994 - March 1999 when the Nash coefficient is 82.2% (Table 19). This simulation is used to fill in the missing values of monthly flows and extend the flow series over the period of 1968-2016. The water balance shows that the REE is the most important fraction of rainfall. Then, the infiltrated water slide is greater than the one running over the watershed. The results show that with the rainfall deficit (-24%), a greater decrease in runoff (-40%) and infiltration (-33%) compared to the REE (-7%) is noted (Table 20). This trend is confirmed on a ten-year scale (Figure 41). However, the proportion of REE in annual rainfall becomes more important in periods of deficit to the detriment of runoff and infiltration. It increases by 41% to 50% while runoff and infiltration decrease from 21% to 17% and 38 to 33% respectively. The lowest runoff rates were observed during the 90s at 190.5 mm and the lowest infiltration rates during the 2000 decade at 351.5 mm.

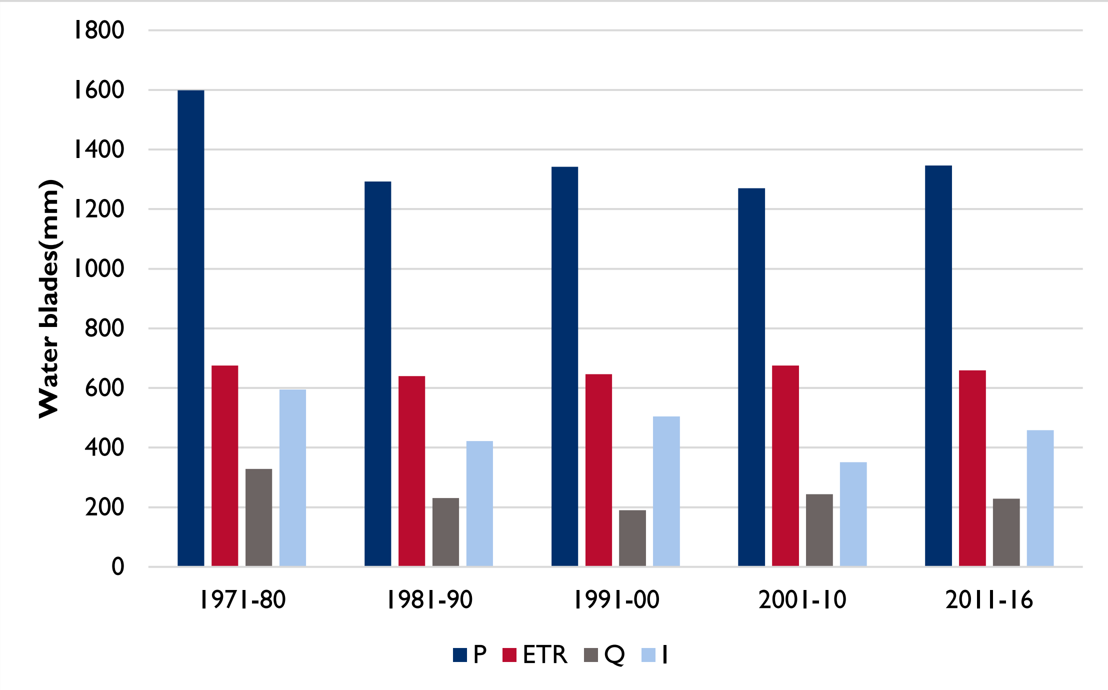
Table 19: Calibration of the GR2M model on the Niouniourou catchment area in Dahiri

PERIODS	NASH CALIBRATION	Parameters	
		X1	X2
01/1994-03/1999	82.2	4.86	0.46

Table 20: Water balance of the Niouniourou catchment area in Dahiri with the GR2M model

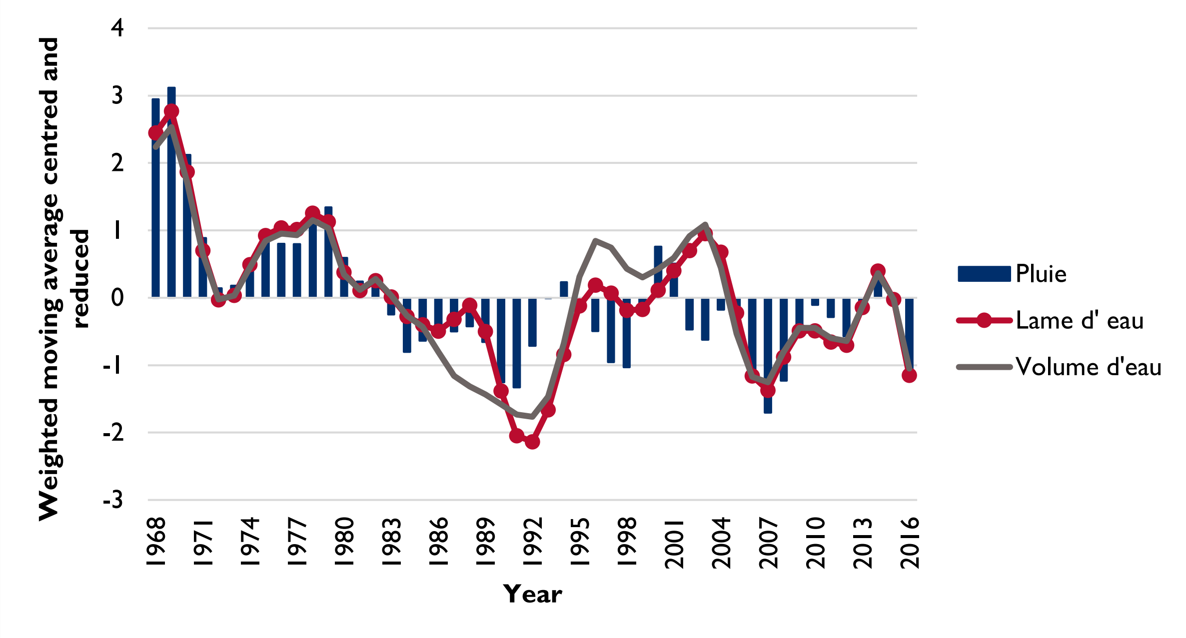
Parameters	Periods		Average deviation (%)
	1968-1982	1983-2016	
Rain (mm/yr)	1714	1307	-24
ETR (mm/yr)	704	657	-7
Runoff (mm/yr)	366	221	-40
Infiltration (mm/yr)	644	429	-33

Figure 41: Water balance of the Niouniourou catchment area in Dahiri with the GR2M model



Interpolation using rain-flow simulation extends the period of analysis of water resource variations to 1968-2016 (Figure 42). Thus, surface and groundwater reflect variations in rainfall with lags of at least one year. The increase in surface flows and water volumes mobilized by aquifers likely to recharge rivers over the period 1994-2004 follows a rise in rainfall over the 1992-1995 and 1999-2001 phases. However, the flows and volumes of water mobilized by aquifers are again declining over the period 2005-2016. The volume of water in the hydrogeological reserve likely to supply the Niouniourou surface runoff in Dahiri also decreased by 40% over the period 1983-2016.

Figure 42: Trends in rainfall, surface flows and groundwater volumes over the period of 1968-2016



Source: Data from the Directorate of Hydrology, Standards and Quality

Overall, the concentration of water chemicals is reduced from the sea to the lagoon, from the lagoon to the rivers that feed it and from the lagoon to the surrounding wells (Table 21). The decrease is slight from sea to lagoon. Thus the salinity goes from 36.6 to 35.9 g/kg and the TDS from 25 to 24.4 g/L. This decrease is more significant from the lagoon to the rivers, almost by half, because salinity and TDS decrease respectively from 35.9 to 18.9 g/kg and from 24.4 to 13.8 g/L. This decrease is very significant from the lagoon to the wells; from 35.9 to 2.7 g/kg and TDS from 24.4 to 0.4 g/L. Within the lagoon even the lowest concentration of chemicals is obtained in the middle of the lagoon (point 8) far from the banks and the ocean with a salinity of 34.4 g/kg.

The pH is basic for the sea and decreases slightly but remains so for the lagoon and rivers from 8 to 7.8 and 7.7. The pH of water from the wells surrounding the lagoon, on the other hand, is acidic. 5.6 on average.

Water temperature variations are small. Thus, it increases from sea to lagoon and river from 30.6 to 31.0 °C and decreases slightly from lagoon to well where an average temperature of 30.5 °C is observed.

Table 21: Physico-chemical parameters of the Fresco lagoon, the sea, surrounding rivers and wells

Number	Type of water	CE (mS/cm)	TDS (g/L)	pH	T (°C)	Salinity (g/kg)
16	**Sea**	50	25	8.03	30.6	36.6
15	**Inlet (Sea-Lagoon)**	49.8	24.9	8.04	28.7	35.2
14	**Lagoon**	49.5	24.75	7.81	31.2	36.6
17		48	24	8.05	32.7	36.4
8		48	24	7.32	29.6	34.4
1		49.2	24.6	7.91	30.7	36.1
2		49.1	24.55	7.9	30	35.5
4		49.3	24.65	7.63	30.9	36.3
19		49	24.5	7.66	32.1	36.2
	Average	**48.87**	**24.44**	**7.75**	**31.03**	**35.93**
9	**Lagoon-River**	32	16.5	7.73	31.1	24.2
10	**River**	27.15	13.58	7.69	31	18.5

Number	Type of water	CE (mS/cm)	TDS (g/L)	pH	T (°C)	Salinity (g/kg)
11		27.76	13.88	7.7	30.7	18.9
12		28.67	14.34	7.63	30.8	19.6
13		26.85	13.43	7.73	31.4	18.4
	Average	**27.61**	**13.81**	**7.69**	**30.98**	**18.85**
3		0.32	0.16	5.5	28.9	3.1
5		1.77	0.88	5.42	31.2	2
6	**Well**	0.24	0.12	5.8	31.2	3.2
7		0.38	0.19	4.98	30.9	3.1
18		1.54	0.77	6.11	30.3	2.2
	Average	**0.85**	**0.424**	**5.562**	**30.5**	**2.72**

4.1.3 NON-CLIMATE STRESSORS

A non-climate stressor is generally a change or trend unrelated to climate that can exacerbate climate hazards. For example, changing drainage patterns and constructing roads and buildings on open land are non-climate stressors for flood risks. Non-climate stressors are also called driving forces or structuring factors. It is generally accepted that: *(i) demography, (ii) economic processes (consumption, production, industrialization, markets and trade), (iii) scientific and technological innovation (iv) distributional model processes (inter and intra-generational), (v) cultural, social, political and institutional processes (including production and service sectors)* remain highly influential or exert significant influence in environmental governance and trajectories. Among the non-climate stressors in Fresco, the main focus should be on: *(i) demography (which is constantly increasing); (ii) urbanization, which follows the same dynamic as demography; (iii) economic and social factors; and (iv) the institutional framework for natural resource management.*

Rapid population growth is a factor in the imbalance of the ecological footprint and biocapacity ratio and can lead to an ecological deficit and an inability of natural ecosystems to meet people's demand for ecosystem goods and services. Urbanization is a structuring factor in environmental trends. Indeed, habitat and living environment remain largely influenced by the degradation of natural resources and the environment. In cities, we are witnessing a development of spontaneous housing. The increasing and uncontrolled exploitation of natural resources coupled with environmental degradation is placing new constraints on economic development and job creation prospects. Finally, armed conflicts are accompanied by a collapse of environmental governance, which in turn leads to accelerated environmental degradation. As a result, the long and patient work of several years or even the natural work of several millennia could be destroyed in no time. Sometimes, destruction causes irreversible damage to ecosystems; this is the case when species are brought to total extinction, or fragile ecosystems are irreversibly degraded, or resources irreparably destroyed or contaminated. All institutional protection systems, such as protected areas, including national parks, become calling areas for displaced persons or combatants, with immediate and often irreversible consequences for the quality of these ecosystems (Dorsouma and Bouchard... 2006).

The desire to promote the rational management of the environment and natural resources has been translated in Côte d'Ivoire into a series of institutional and legal measures that are constantly evolving in the international context where the rational management of the environment has become an international priority. About administrative governance, the Fresco region is characterized by the juxtaposition of two management regimes: the public regime of the State and the rural land regime. The public regime of the State: this regime applies by way of example to the entire Fresco region and particularly to the forest reserves of Port Gauthier. This sector is owned by the State, which has delegated its management to the Société de Développement des Forêts (SODEFOR); Sankaré and Aka. 2016).

The rural land regime applies to the sectors of the wetland outside the forest reserves of Port Gauthier as well as in the vicinity of the wetland. This regime grants people usufruct right. Under this regime, there is customary land, land not owned by any individual either than the stool, land owned by public authorities and individuals. In functional terms, the management of these lands is carried out by delegation from the State to the regions, municipalities and private and legal entities. Act No. 98-750 of 23 December 1998 on rural land; grants individuals in these areas the right to own and transfer land titles. It is within these areas that exploitation activities (agriculture, forestry and mining, etc.) and resource extraction activities (hunting, fishing, logging, etc.) as well as urbanization and all other socio-economic activities are developed (Sankaré and Aka. 2016). The design and implementation of the national policy for the protection of the environment and the management of natural resources is the responsibility of the Ministry of Health, Environment and Sustainable Development. In order to exercise its powers, the ministry has at its disposal attached and decentralized services, central departments and National Public Establishments under its supervision.

In addition to the Ministry in charge of the Environment, which works in the fields, other ministries have some of their attributions and missions that have close links with environmental issues. In particular, the Ministry of Agriculture and Rural Development, Ministry of Water and Forests, Ministry of Water Resources, Ministry of Animal and Fisheries, Ministry of Industry and Mines, Ministry of Health and Public Hygiene, Ministry of Construction, Ministry of Housing, Sanitation and Urban Development. The process of decentralization and disengagement of the State was launched in 1997 with the territorial division and in July 2003 with the transfer of powers to decentralized bodies. In principle, municipalities are now responsible for protecting the environment and managing natural resources. However, with the crisis, this policy is hardly implemented (Sankaré and Aka. 2016).

Universities, research institutes and laboratories have a good reputation and their relationship with state environmental agencies is perfect; based on a long tradition of cooperation. All these institutions are involved in the various national communications on the various conventions.

In Côte d'Ivoire, however, NGOs, associations and movements are active in advocacy, information, awareness-raising and communication on environmental issues. Agricultural cooperatives seem to be better organized, but their objective remains production and marketing; hence there are real opportunities to integrate and put into practice climate-smart agriculture. Environmental aspects are not taken into account at this level, but sustainable development requires it today.
Finally, since 1938, Côte d'Ivoire has signed and ratified some 40 international conventions, agreements and treaties relating to the environment. Indeed, according to article 56 of the Constitution,"treaties duly ratified, as soon as they are published, preside over related laws". Furthermore, in the absence of national laws on a given subject, Côte d'Ivoire makes use of provisions of international conventions (Sankaré and Aka. 2016).

In addition to the official governance of natural resource management, there is also traditional governance over the same resources (Sankaré and Aka. 2016). Thus, in Fresco, there are locally different types of natural resource management and use. The following are other types of resource management:

- **land management**: the local population manage the land themselves. Lands are transferred from father to son. In case of land lease, the whole family is kept informed and the lease is for growing a given crop and for a given period. Otherwise, the land is taken back by its owners;
- **mangrove management**: It is forbidden to cut mangroves. Any contravention of these local regulations is sanctioned by the village authorities. However, bad-mannered individuals hide to cut mangrove woods to sell them as firewood for fish smoking;
- **management of the sea and fish products:** there is no local way of managing the sea. Only the village authorities have customary law over the sea and charge taxes to foreigners who fish there. In addition, only local women are allowed to trade in lagoon and marine products. Faced with this situation, some fishermen sell their products in other marine regions to earn more money;
- **inlet management**: the inlet that connects the lagoon to the sea closes regularly. A local family has specialized in its opening. This family is regularly solicited to open it for money.

4.2 SUMMARY AND CONCLUSIONS

Fresco's annual rainfall series experienced a break in rain stability 1982. It is a late break (Brou. 2005) because it occurred after the general period of break in rainfaill in Côte d'Ivoire 1966-1971. This type of break is observed on stations located in the North or on the coast (Paturel et al. 1997; Fadika. 2012) such as Fresco and causes higher deficits. The average gap of -24% over the period 1983-2017 compared to the period 1968-1982 is higher than the average of -21% in Côte d'Ivoire (Servat et al... 1999). This result also confirms the late breaks already observed on the series of two other stations located on the Ivorian coast, but further to the west. In 1974 in Sassandra and 1994 in Taboo with deficits of 27% and 36% respectively (Fadika. 2012). However, these series were less extensive than the Fresco series. This shows the importance of this variation that appears on the Fresco series, which takes into account two additional decades and does not begin until 1968.

Analysis of rainfall by decade shows that the 1970s is the most watered decade with at least 100 mm more than the others. This result confirms the previous one (rupture in 1982) and those obtained in Sassandra and Taboo where the 1970s were not in deficit (Fadika. 2012). The decline in rainfall began or worsened in the 1980s on the Ivorian coast. But unlike these two stations in southwestern Côte d'Ivoire and the neighbouring east of Grand Lahou, the rainfall deficit did not increase further in Fresco during the following decade (1990), but during the decade of 2000. However, during the 90s, there was a persistence of poor rainfall conditions observed during the 80s and in most of Côte d'Ivoire (Brou. 2010).

There is a correlation between the increase and decrease of the interannual rainfall variability. The coefficients of variation of the height series per decade increase overall from 0.22 to 0.31. This shows little irregularity in rainfall levels that also occurs at the monthly level. The month of March becomes a dry month from the decade of 2000 onwards, extending the main dry season by one month and shortening the long rainy season as noted by Brou (2010). Moreover, the contribution to the total annual rainfall of the major rainy season is reduced over the decades to the benefit of the short rainy season.

The temporal variability of rainfall in intertropical Africa is the result of combined effect of many factors. However, significant relationships have been noted between thermal anomalies in the tropical Atlantic Ocean and some regional interannual precipitation trends in Côte d'Ivoire (Bigot et al, 2002; Bigot et al, 2005). An increase in rainfall on the Ivorian coast is therefore, preceded by a decrease in ocean surface temperatures (OST) in the Gulf of Guinea in May (Kouadio et al... 2002). Similarly, an abnormal warming of the southwest Atlantic TSOs would explain a significant part of the downward trend in rainfall in Côte d'Ivoire after 1970. In addition, the increase in albedo resulting from deforestation caused by human activities (urbanization, agriculture, bush fires, etc.) is a cause of climate variability (Assani. 1999). The one caused by overexploitation of the forest in several regions bordering the Atlantic Ocean and the Gulf of Guinea has certainly contributed to increasing rainfall deficits (Servat et al... 1999), because the modification of the forest cover results in a reduction in continental water vapour inputs to the atmosphere and thus contributes to the decrease in rainfall by weakening the monsoon. Observation of past climate trends at the local level shows different findings:

- an increase of 0.5 °C over the last 50 years (average annual temperatures);
- the downward trends observed since the early 80s in precipitation trends;
- an average sea level rise of about 19 cm between 1961-2010;
- a clear upward trend in the frequency of floods, dry periods and storms.

Over the next few decades, the trends observed will continue and even increase according to the latest IPCC research. Despite the many uncertainties inherent in climate projections, the scenarios show that over the next few decades:

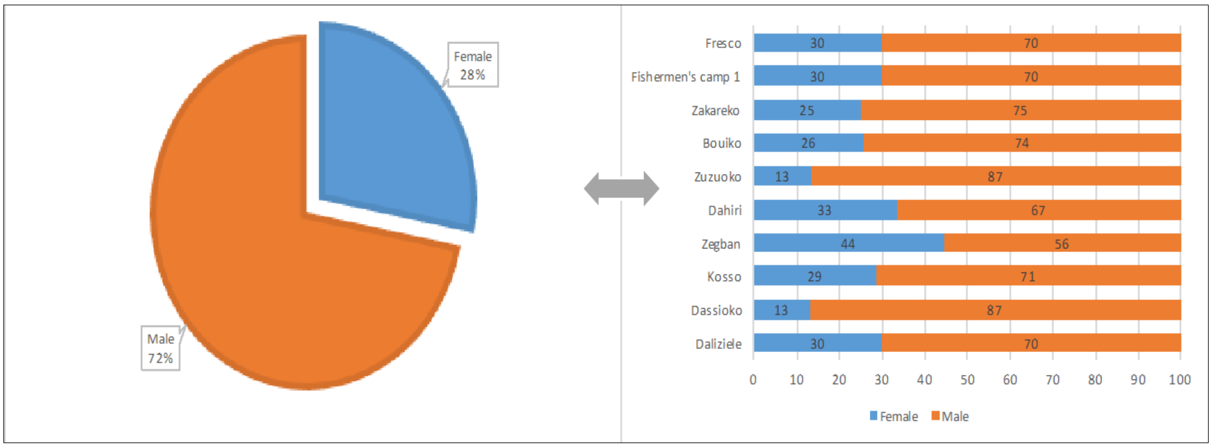
- an increase in average temperatures in the region by up to an additional 1.0°C in 2050. 1.5°C in 2100 for the CPR scenario 4.5 on the one hand and up to 2.0°C in 2050. 4.0°C for CPR scenario 8.5 on the other hand;
- an increase in periods of high heat;
- a decrease in seasonal rainfall associated with a change in the distribution of rainfall, thereby accentuating the high intra-seasonal variability;
- an increase in the frequency and intensity of extreme events;
- a sea level rise of +0.26 m for the RCP 4.5 scenario to +0.63 m for the RCP 8.5 scenario by 2100.

5.0 COMMUNITY AND ECOSYSTEMS SENSITIVITY

5.1 COMMUNITIES AND HOUSEHOLDS

During the surveys, we identified the socio-demographic characteristics of the Fresco environment. The gender distribution of the households interviewed is 72% (male) and 28% female. Despite the deliberate attempt to reach out to and interview women during the field survey, there were constraints due to the existing socio-cultural and political arrangements in the surveyed areas. Figure 43 below provides details on gender dynamics in the Fresco landscape. Compared to the situation at the national level (RGPH. 2014). Fresco statistics show a balance in favour of men.

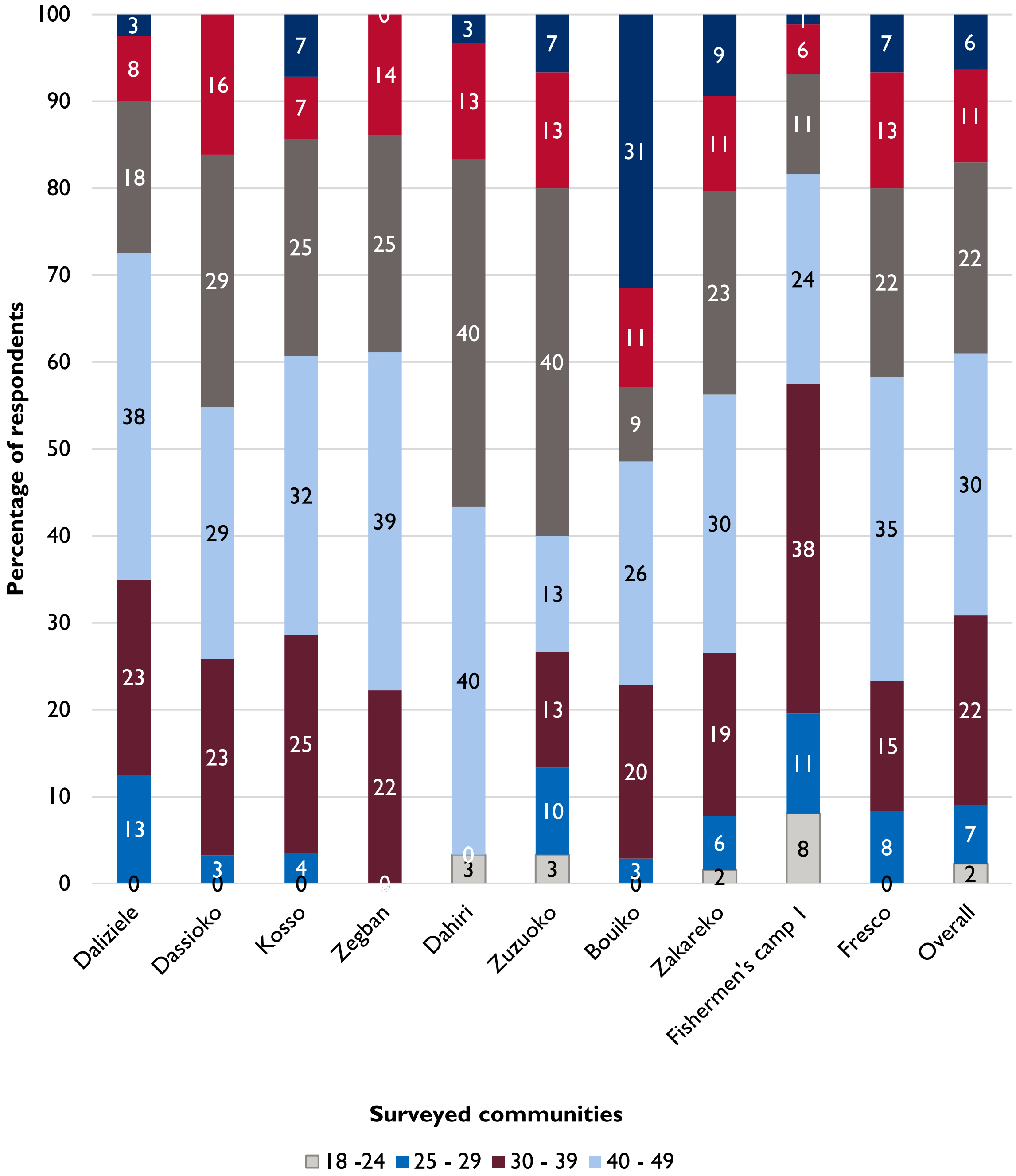
Figure 43: Distribution by gender category of respondents interviewed in the Fresco lagoon landscape



Source: Fresco Vulnerability Assessment Survey Data

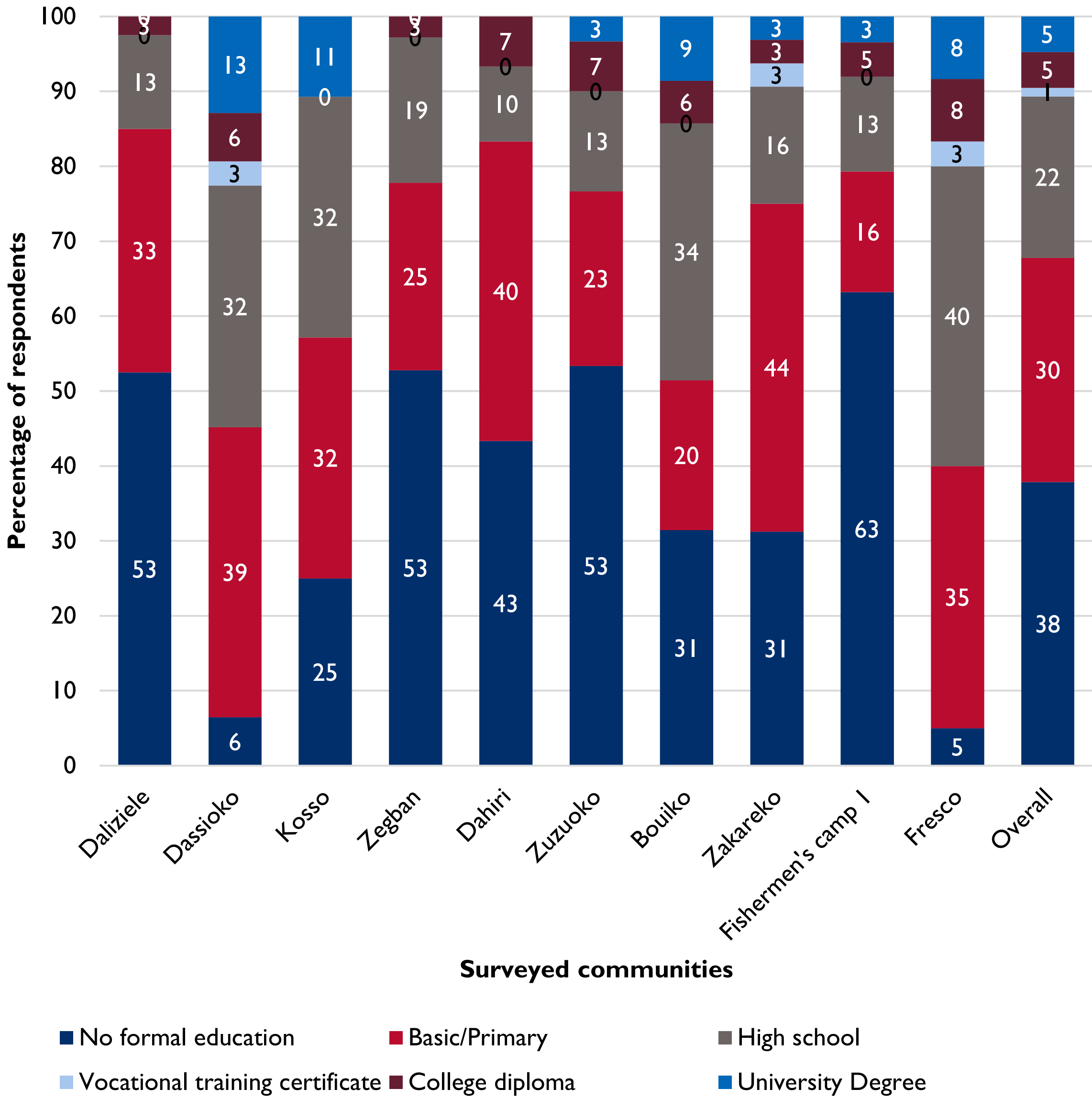
According to the household survey, age groups 30-39 (22%). 40-49 (30%) and 50-59) 22%) dominate the population of the region (Figure 44). This indicates an ageing population in the region, which is mainly rural. The immediate implication of such a situation is that there could be a continued decline in the human capital available to support productivity and livelihood supply capacity in the region. This could lead to problems in the future with unavailability of manpower for proper implementation of climate related measures. As for agricultural productivity, it could also be negatively affected in the medium and long term, and therefore, affect the sustainability of livelihoods in the area.

Figure 44: Age distribution of the population in the surveyed communities of the Fresco landscape by age group



During the household surveys, it generally emerged that the level of education in the Fresco landscape can be classified as low. The majority of respondents (38%) have no formal education; 30% say they have attained basic education (or primary school). Only in the communities of Zakareko and Dahiri did the majority of respondents affirmed having a basic or primary education; indeed, rates are above 40% (Figure 45).

Figure 45: Educational attainment of populations in the Fresco landscape



Ecosystems, like the communities on which their lives depend, are directly or indirectly affected by climate change. However, the intensity of these impacts is subject to spatial and temporal variability. The closer communities or ecosystems are to an area at risk (e. g. coastal front), the more sensitive they are. Sensitivity is directly related to the risks at a given location. For example: Sahel communities or ecosystems will be more prone to drought while coastal areas are rather sensitive to sea level. etc. Based on household surveys, the results on the impacts of changing climate variables on the Fresco Lagoon landscape are described below.

The vast majority (93%) of fishing community households reported that their perception of sea level rise was high, while the rest of the communities surveyed in the Fresco landscape did not consider sea level rise (Figure 46) in the same way. Figures 47 to 50 provide information on how communities perceive other climate hazards.

During group discussions with the communities, they drew our attention to the fact that in some places, high salinity affects soils and crops. This has possible negative implications for agriculture and therefore, for food security. The same is true of crop reductions and yield declines that people are already complaining about; they relate this to climate change. They also relate to the high variability and irregularity of rainfall that increasingly characterizes the ever-shorter rainy seasons.

Figure 46: Community perceptions of their exposure to sea-level rise

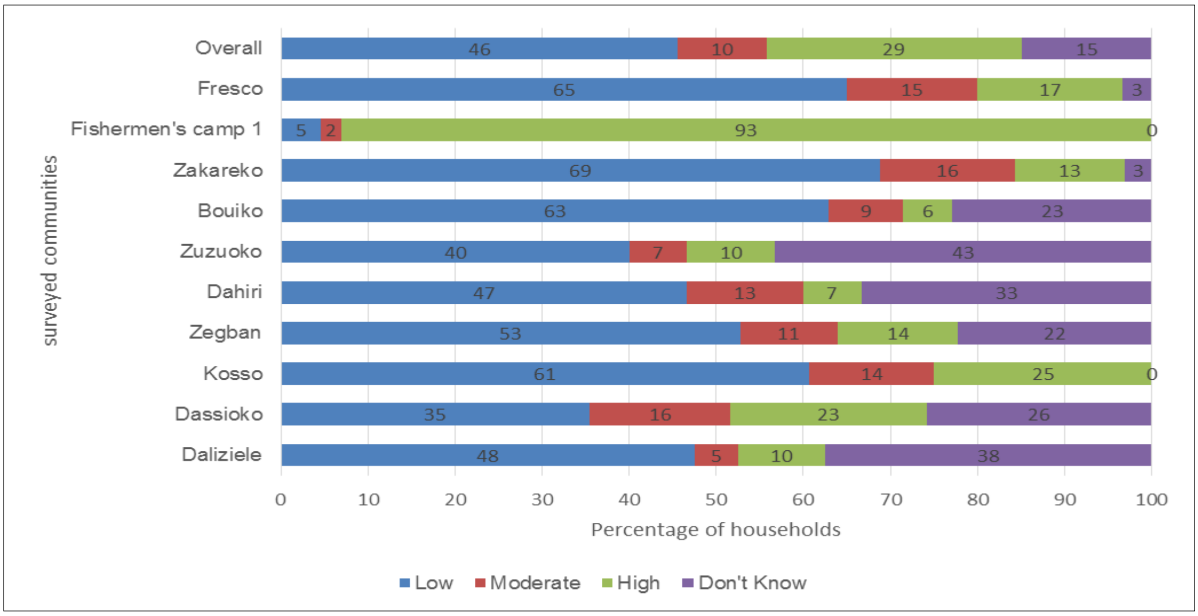


Figure 47: Community perceptions of their exposure to severe storms

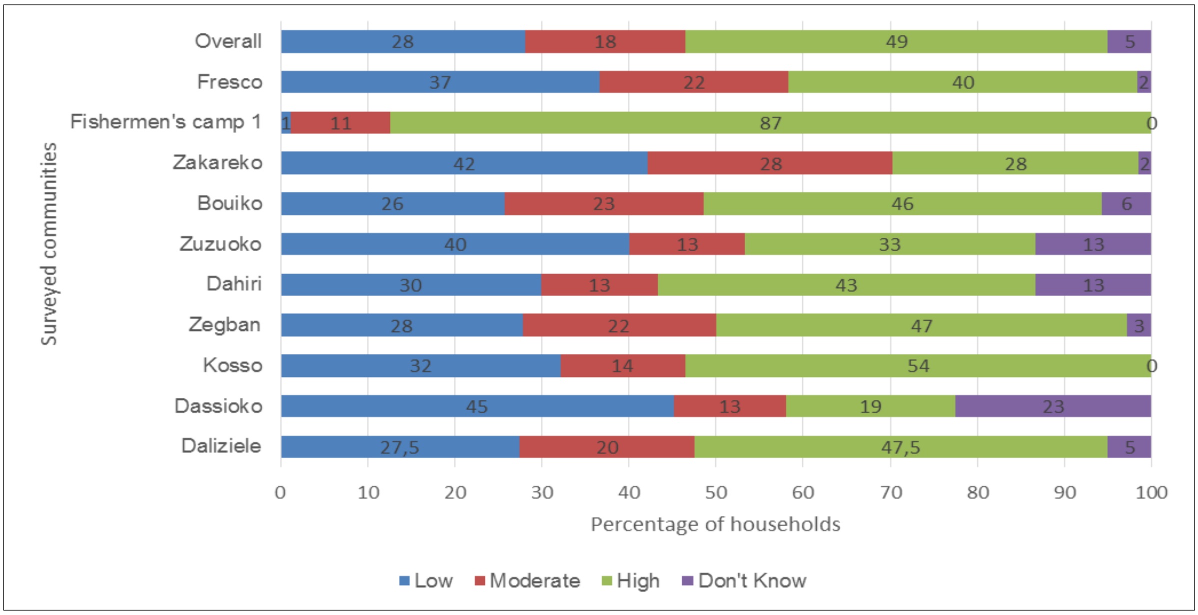


Figure 48: Community perceptions of their exposure to storm surge rise

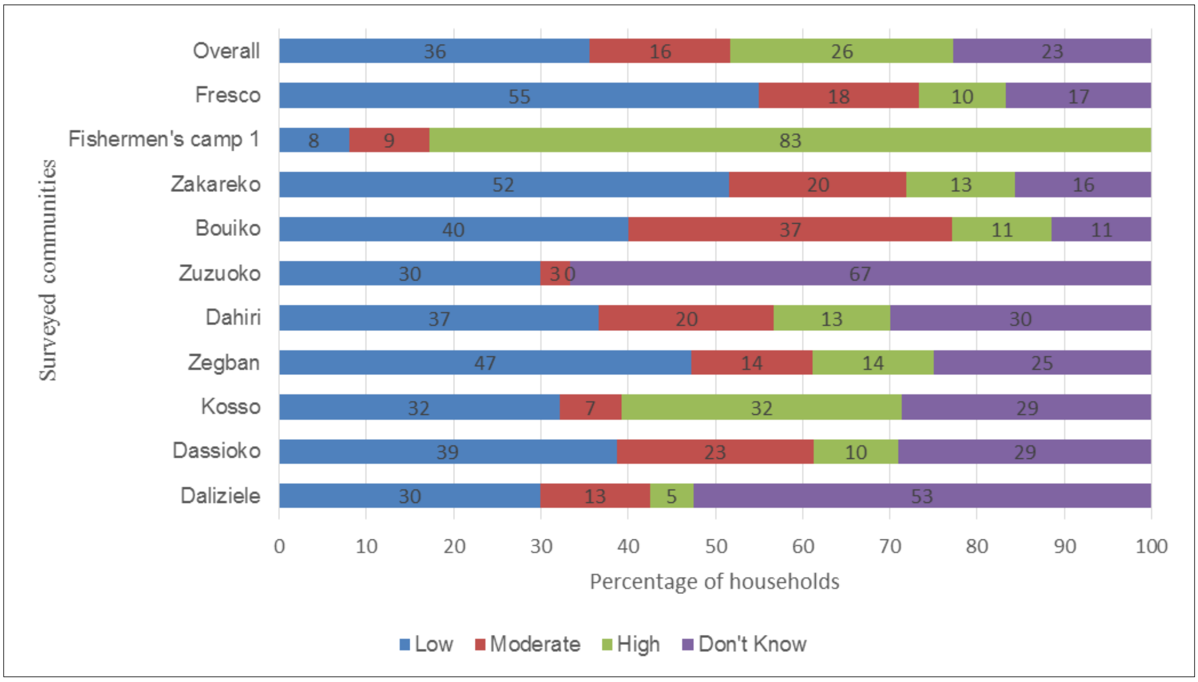


Figure 49: Community perceptions of their exposure to prolonged droughts

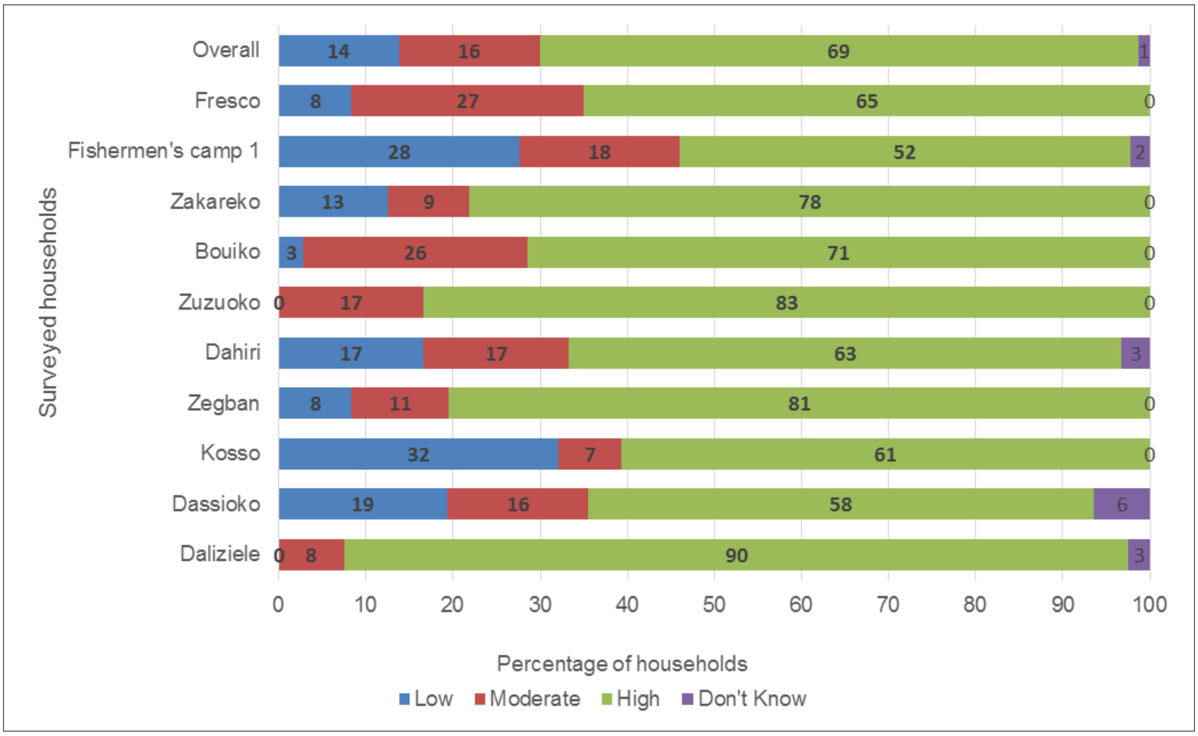
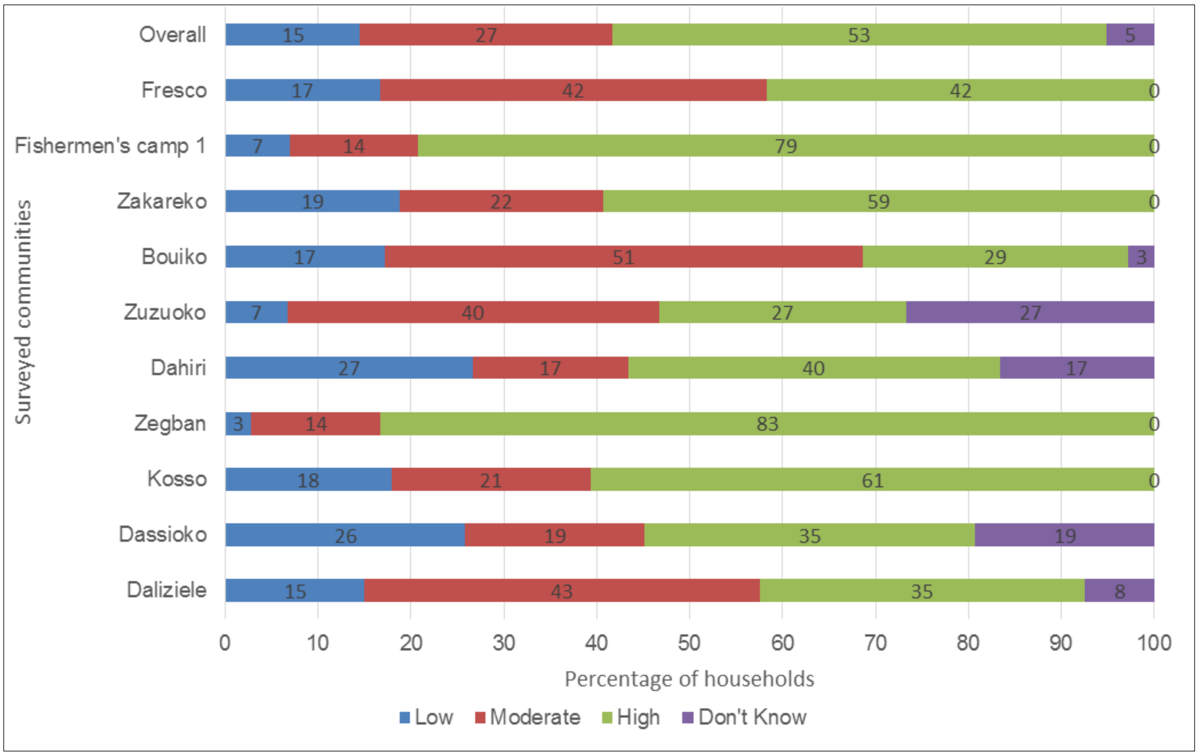


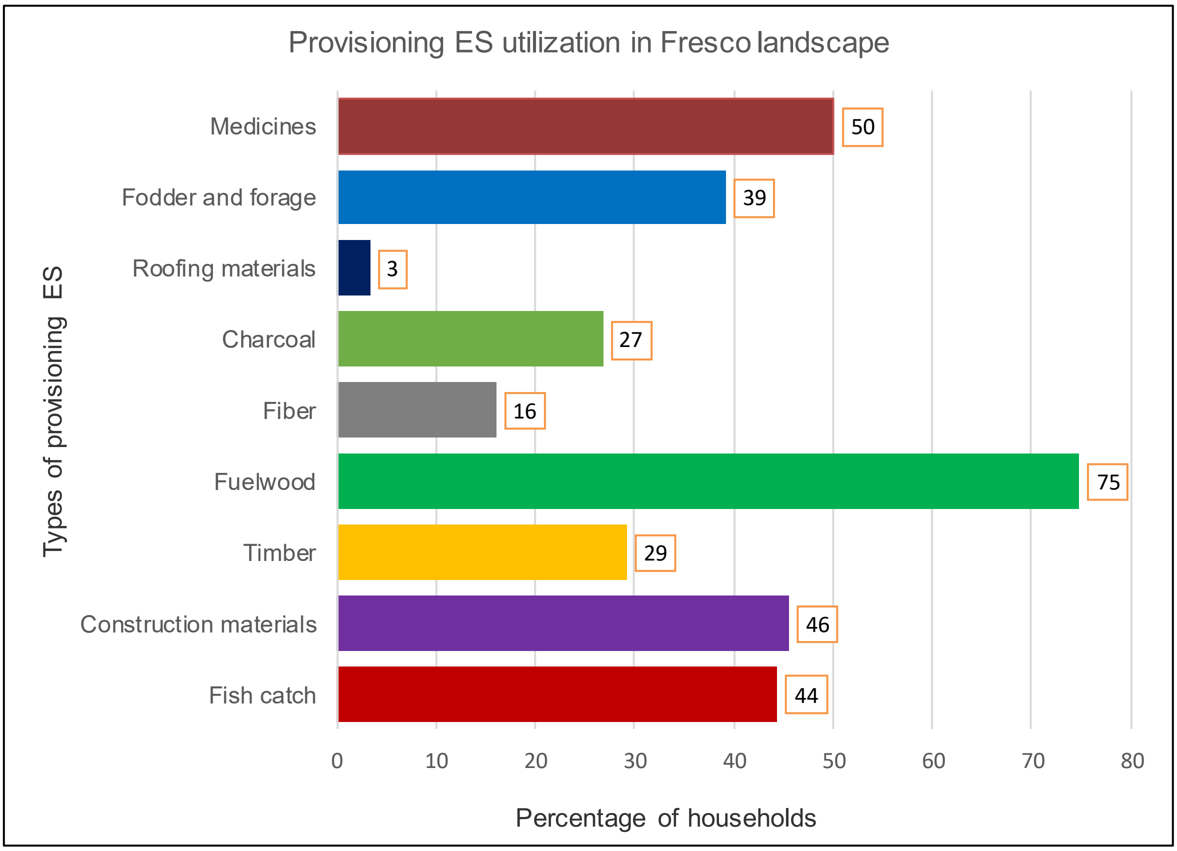
Figure 50: Community perceptions of their exposure to extreme rainfall



5.2 SENSITIVITY OF CROPS AND THE VALUE CHAIN OF ECOSYSTEM SERVICES TO CLIMATE CHANGE

Similarly, in the Fresco lagoon landscape, nine (9) major ecosystem services of supply, considered essential by communities (Figure 51), are really threatened and could reach critical thresholds. The provision and accessibility of these services have faced new challenges in recent times. Undeniably, many residents have complained that they now travel further (and therefore a longer distance) through the forest to access these ecosystem services. It was also brought to our attention that more and more communities are clearing more lands to expand their fields or establish new plantations. These actions or behaviours, of which populations are aware, in turn affect the availability of resources, especially since population growth is a factor in environmental degradation. All these elements also reinforce or even exacerbate the sensitivity of ecosystems to climate change. Similarly, fishing communities report that mangroves are cut at a very high rate for use as fuelwood and building materials. The use of ecosystem supply services such as fuelwood, pharmacopoeia (medicines), building materials and fodder are the most popular use categories (Figure 51). Inventory levels for these services have decreased significantly; at rates faster than any potential for restoration or regeneration. The implications for households that depend directly on such ecosystem services reveal that they may be potentially even more vulnerable to climate change; because they are already very vulnerable and because of the growing sensitivity of ecosystems to these phenomena. Serious threats to the sustainability of ecosystem services are already looming.

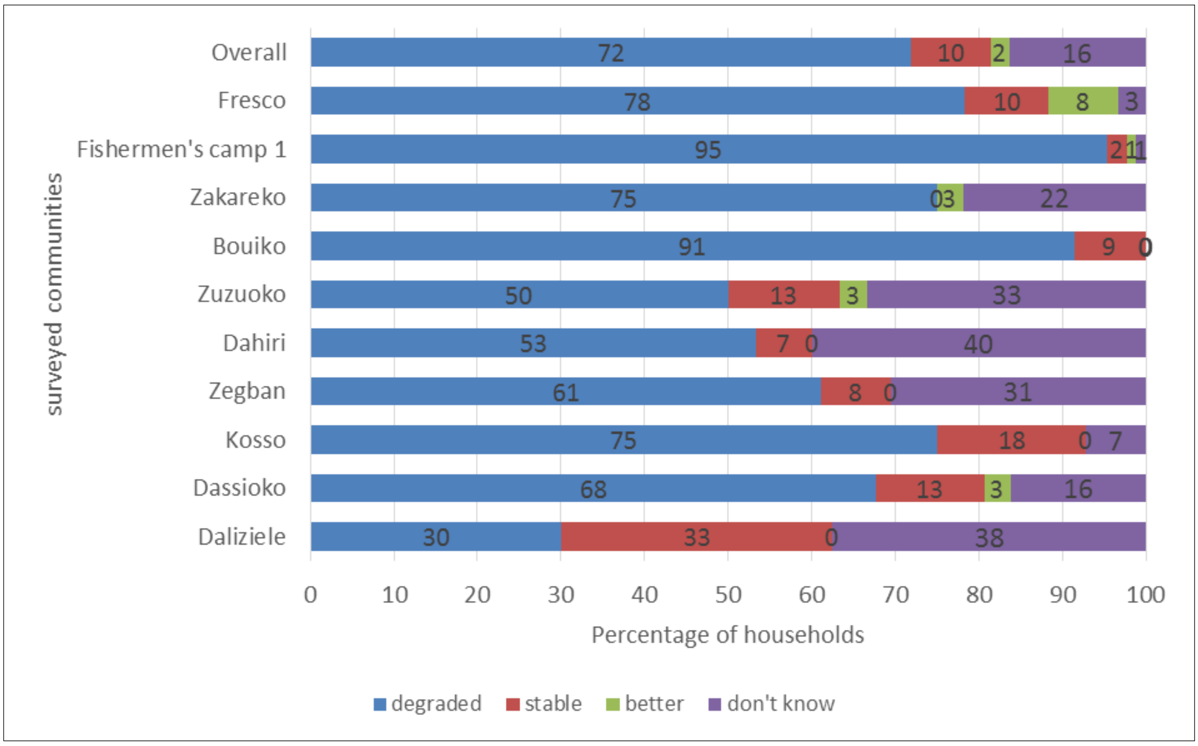
Figure 51: Perceptions on the collection and use of ecosystem supply services in the Fresco landscape



Of course, the collection and use of different ecosystem services (ES) for supply varies widely among households, as other studies in the West African sub-region (UNDP. 2003) have shown. Fuelwood is the most widely used ES in the Fresco landscape; according to the communities, four (4) communities (Dahiri (100%), Kosso (93%), Zegban (92%) and Zuzuoko (90%) are prominent in fuelwood collection; this is not new in itself and other work confirms this trend in rural Africa (Hunter et al. 2007). But. one of the consequences of this observation is that there is a higher risk of land clearing for agriculture. Behind this first risk, due to deforestation for agricultural purposes, there is the risk of soil leaching, especially for those located at the top of the basin, which weakens a major factor of production for people's food security. This leaching resulting from water erosion phenomena following the destruction of the vegetation cover contributes to the sedimentation and silting up of rivers and the Fresco lagoon, jeopardizing the future of ecosystems. Building materials remain predominant according to households in Gnago 1 (70%), Fresco (57%), Dassioko (55%) and fishermen's camp 1 (51%), while the exploitation of service wood is more important for Fresco (53%). Daliziele (50%), Dassioko (48%) and Dahiri (40%).

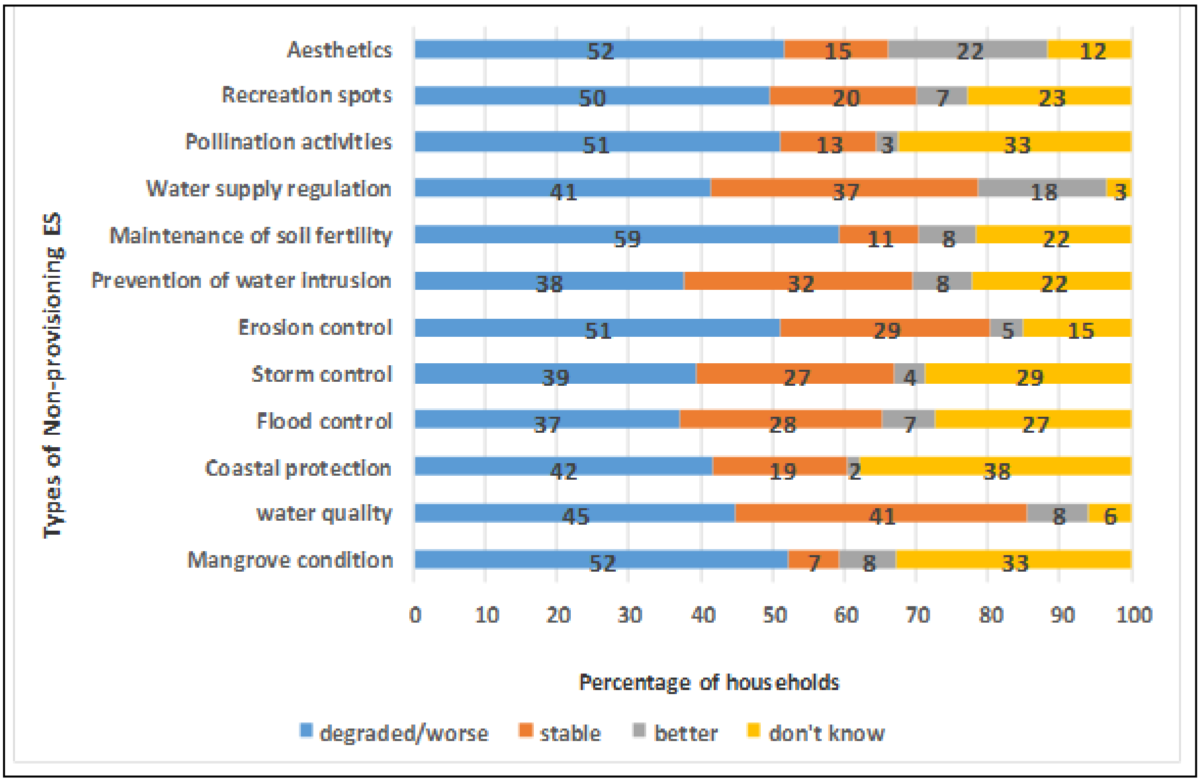
In the Fresco lagoon landscape, fishing remains a key socio-economic activity for the communities living there; about 44% of households are engaged in this activity. Disparities are observed: the highest values are recorded at fishing camp 1 (79%) and Kosso (68%). In Fresco (47%), about half of households report that their dependence is linked to fishing to support daily and seasonal livelihood strategies. However, the majority of communities (72%) are seeing a decrease in the amount of catches and big fishes are becoming increasingly rare. Households in fishing villages had the highest percentage of responses (95%) affirmed the decline in catches of big fish. followed by the community of Bouiko (91%) and Fresco (78%). Figure 52 provides further information on the status of large fish caught in the lagoon and surrounding watersheds. Behind these figures, it is easy to understand the quantities of fish as an ecosystem service in lagoon and/or marine areas are in decline. All this illustrates and confirms, convincingly, that SEs are not only in decline, but they are beginning to reach fairly threatening levels, and that if this dynamic is maintained, the vulnerability of populations should increase.

Figure 52: Perceptions of catching large fish in the Fresco lagoon landscape



Environmental degradation reported by populations does not also spare other non-provisioning ecosystem services (e.g. regulatory, support and cultural services). Indeed, if they are not severely degraded, they are worse than in the past and they report fragility, which augurs a worrying trend, as they may further increase the vulnerability of communities (Figure 53).

Figure 53: Perceptions of regulatory, support and cultural services



Predominantly rural area, many households depend, to a large extent, on support for the livelihoods provided by ecosystem services. In recent years, many households in the region have faced livelihood problems. In this regard, it has been identified that some factors influence efforts to meet the daily and seasonal needs of communities (Figure 54). These factors affect agricultural produce in one way or another, whether they are food crops or cashcrops, but also the entire value chain. The use of pesticides and other chemicals by food crop and plantation producers resulted in a high percentage (57%) of eutrophication in the lagoon. This affects not only food crops, but also the chemical balance of water resources that eventually kill certain species in lagoons and rivers, thereby affecting biodiversity. The mediocre or even degraded nature of ecosystem services supporting food crop production is another challenge that communities have clearly identified. In addition, there is no dynamic microcredit system to support small farmers. Similarly, the expected efforts to popularize good practices in order to avoid additional pressure on environmental resources are absent. However, there are warehouses in Zegban and Fresco to store cocoa beans; for food crops, there is no storage facility in the region. Other factors include high population growth (65%), destructive fishing practices (62%), sand extraction (60%), overfishing (58%) and eutrophication (57%), which pose the greatest livelihood challenges in the Fresco Lagoon landscape (Figure 54; photo plate 4).

Figure 54: Perceptions on the drivers of change in ecosystem services in the Fresco lagoon landscape

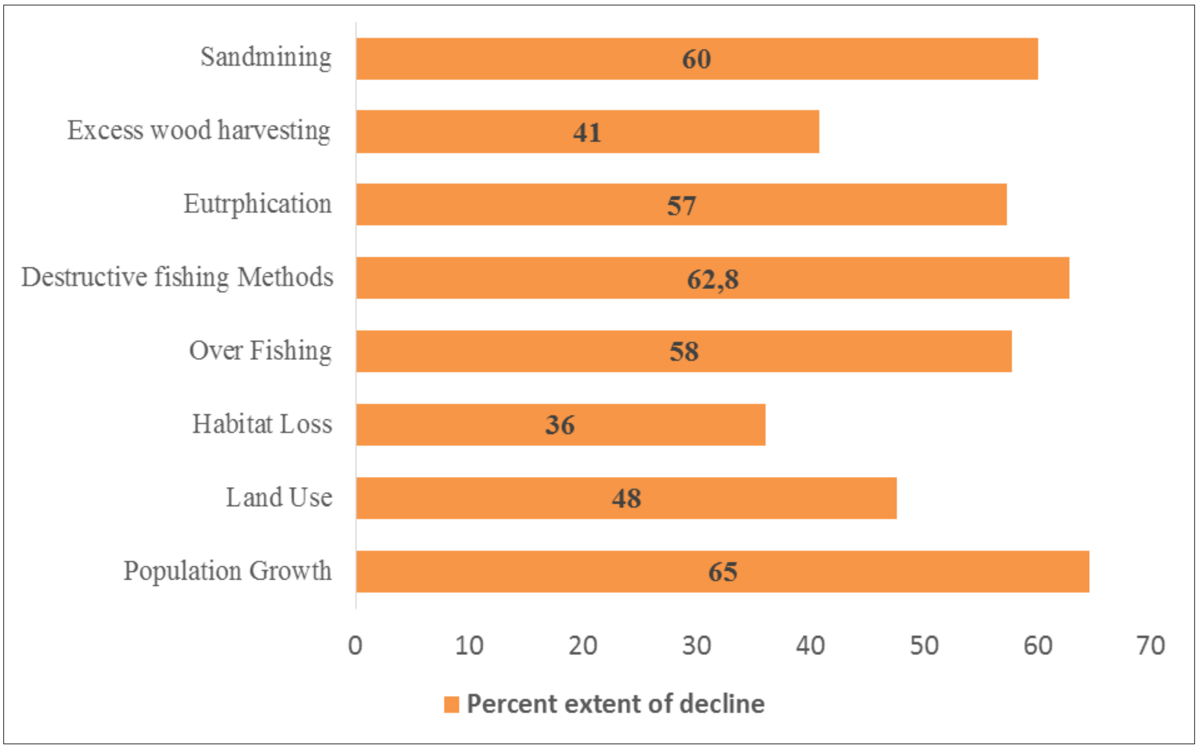


Photo gallery n° 4: Some subsistence activities of men and women in the Fresco region

Table 22 below shows the nature of commodity value chains in the Fresco area. Indeed, the study revealed that no significant added value was provided for any of the products recorded. Plantations, food crops, fish, wild fruits and game are only supported by a simple minimum treatment to improve shelf life for use in the area or beyond. Thus, this situation has enormous implications for post-harvest losses of essential agricultural products as well as for fish catches. Nevertheless, the same situation also shows that any conscious intervention in the full development of fish, cassava and selected plantation crops could offer more livelihood options along the different value chains of these products. More targeted intervention in high-potential value chains can permanently change the vulnerability status of households participating in the chain. A more detailed assessment of the potential of the value chain is still recommended to better inform an intervention area and a product.

Table 22: Nature of commodity value chains in the Fresco area

Commodity or Product	Nature of current added value	Potential
	Plantations	
Rubber	Rubber plantations owned by individuals and companies exist in zones 2 and 3 of the study area. Raw rubber is harvested and sold in raw form for export.	Many cocoa plantations are being replaced by rubber trees largely due to the devastating effects of the swollen shoot disease of cocoa. Excellent quality basic material even if additional on-site treatment is recommended
Cocoa	Minimum treatment	Farmers' interest in zones 2 and 3 is reduced due to the high loss of cocoa plantations in the event of swollen shoot epidemics that have affected production in the latter years. Additional investments in cocoa value chains in the region are not recommended
	Foodcrop	
Cassava	Minimal process to improve shelf life. Also processed into a local food called "Atiéké"	*Atiéké has additional value chain development potential. This includes improving packaging for sale in premium super markets and for export*
Maize	Minimum treatment required to improve shelf life	High-quality basic raw materials for value-added maize processed into flour. Corn flakes and popcorn for sale in high-end supermarkets in cities
Plantain	Minimum treatment required. Ripe plantain is usually fried for sale (food vendors)	Good raw material supply capacity. Other innovations in processing and packaging for improved value chains and high-end markets
	Fish	
Catches from the lagoon	Sold fresh to food vendors	Storage facilities such as cold freezers

Commodity or Product	Nature of current added value	Potential
Ocean fish catches	Sold fresh and also smoked for more conservation	Raw materials available and in quality. Continued processing into fish fillets for superior quality market potential.
Others		
Game	Minimum treatment	
Firewood for firewood	processing of charcoal	Low potential because it has implications for overexploitation of ecosystems.
Wild fruits	Usually for domestic consumption	Minimum or even low commercial potential

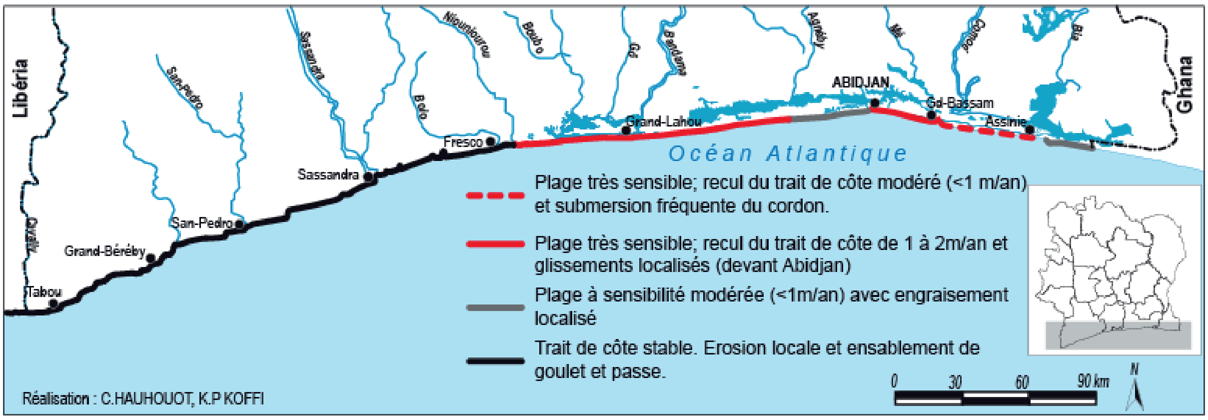
5.3 MANGROVES

The importance of the mangrove ecosystem in Fresco requires us to pay particular attention to it. Indeed, mangroves are tropical ecosystems that need a temperature between 20 and 30°C for their development. Since the end of the 19th century, the earth has experienced temperature increase from 0.6 to 0.8°C. Projections suggest an increase of 2 to 6°C by 2100 due mainly to human activities (Houghton et al. 2001). For Field (1995), most mangroves will only be affected by such temperature increases if they exceed 35°C. An average temperature of 25°C is favourable for mangrove development. The trees then produce many plants that are useful for regeneration. Below 15°C. The development of mangrove trees slows or stops (Hutchings and Saenger. 1987). Above 35°C, the temperature causes significant heat stress. A thermal variation between 20 and 35°C, as in the Fresco region does not have a major impact on ecosystems (Saenger and Moverly. 1985).

Rainfall is an essential element for tropical forest ecosystems. Good precipitation allows the groundwater table to be replenished at the same time as it provides water nutrition for living organisms. In mangroves, freshwater inputs allow salinity to be controlled to an acceptable level for biodiversity development. Low rainfall increases salt levels and creates significant physiological stress for both flora and fauna. Mangroves reach their maximum growth for low salinities around 5%.

The sensitivity of ecosystems to the effects of climate change manifests itself in several ways, depending on the type of ecosystem, the geographical location, the way the ecosystem functions and the intensity of the phenomenon. Mangroves, land forests, swampy forests and meadows and water bodies have more or less different sensitivities to atmospheric phenomena. The coastline of the Fresco lagoon landscape has beaches whose sensitivity varies from moderate sensitivity with localized fattening to the west of the cliffs, to very sensitive, recoil and localized sliding to the east (MINSEDD. 2017). Figure 55 below shows the variation in coastal sensitivity along the Ivorian coast.

Figure 55: Sensitivity map of the Ivorian coast



Source: MINSEDD. 2017

Ecosystems are affected by flooding, especially during periods when the pass is closed. The surface area of the lagoon can be flooded over a relatively long period of time, which creates nuisance for all biotopes and biocenoses. The hydrographic network gives an idea of the variations in the limits of the lagoon during the different periods of flooding and otherwise (dry and rainy seasons). The Fresco lagoon remains a biodiversity hotspot. However, it is nevertheless adversely affected by temperature variation, precipitation, sea level rise, etc., which affects the potential resilience of ecosystems. Also, it seems important to us, before addressing the important chapter on the recommendations, to recall two essential observations on which the future of Fresco's mangroves depends, all forest ecosystems and associated biological diversity. This is the instability of the pass or the estuary between the ocean and the lagoon and trawling in front of the same pass.

Another particularity of the sensitivity of the Fresco wetlands is that they are connected to the Atlantic Ocean by an unstable pass that closes annually when the swell of ocean origin overwhelms the river current of continental origin (photo 5). This situation varies the water surface area of the complex from 17 km^2 during the dry season to 29 km^2 during the closing period of the pass and during the peak of the season.

The closure of the pass has negative consequences on the mangrove ecosystem and wildlife diversity (Egnankou. 1997). Indeed, when the pass closes, the lagoon behaves like a closed lake; the water becomes stagnant and its level rises. The physico-chemical conditions of water are changing. Plant debris and other living organisms that die precipitate to the bottom and create a more anoxic environment that is unbearable for both aquatic flora and associated fauna. Indeed, the rise of water is very harmful to the regeneration of mangroves. Because, young shots are submerged by the water that has become anoxic. Prolonged immersion of the plants causes mortality of the plants, and the shrubs. During this period, semi-aquatic animals find their habitats flooded and die as a result.

When the pass is open, the contact between the ocean waters (salty) and those of continental origin (fresh) causes these waters to mix and give brackish water that is more tolerable by most living animal and vegetable organisms. The normal circulation of estuarine waters makes it possible to maintain the ecological balances of the environment necessary for the renewal of resources. **Hence the need to organize a rigorous monitoring of the functioning of this pass; to open and maintain it each time it closes in order to create the appropriate ecological conditions for the development of mangroves and other associated ecosystems.**

Photo 5: Open Fresco Pass (16 February 2018)

The opening of the pass is done following a traditional ceremony. Using a simple technique with light equipment and at a lower cost. The opening operation of the pass can be estimated at about 250,000 FCFA (two hundred and fifty thousand CFA francs). The traditional ceremony, which consists of a kind of "request for authorization" and during which food is prepared for the "geniuses" known as "protectors", is, according to the Godiés natives, mandatory before any action is taken to open the pass.

To understand the harmful action of trawlers fishing in front of the pass, we must question the recycling of nutrients in the mangrove ecosystem that the functioning of the latter requires, according to Blasco (1983), the recycling of nutrients in the mangrove ecosystem operates in a closed circuit initially before opening up to the ocean. Broadly speaking, it proceeds as follows: the litter produced by mangroves or introduced by upstream systems and the nutrients resulting from its decomposition accumulate only partially on the continuously wet soil. They are largely evacuated to the open sea. In other words, when plant debris (leaves, fruits, twigs, etc.) falls to the ground, it is inoculated and surrounded by microorganisms such as bacteria and especially fungi of the phycomycetes group. These micro-organisms then ensure the progressive decomposition of this primary products. At the end of the transformation, elementary particles are obtained, each covered with microorganisms very rich in proteins. These nutrients are used by all wildlife that stay in mangrove estuaries for a short period of their lives before migrating offshore to further their development and populate marine and coastal waters.

The presence of trawlers in front of the pass is a danger for the development of biodiversity. In their fishing activities, trawlers catch all aquatic fauna and thus prevent the biological cycles of these animals from coming to an end. This poses a real danger by renewing the stock of fish resources and destroying biological diversity. **Hence the need to protect the pass from the surrounding areas, including the associated maritime areas.**

In general, the elements of flora and fauna are very sensitive to extreme climate variations. Rainfall, temperature and flooding create stresses on the lives of plant and animal species. In mangroves, low rainfall increases the salt content of the environment, which can change from brackish to over-salted water; this creates significant physiological stress for both flora and fauna. Mangroves reach their maximum growth for salinities of around 5%.

5.4 WATER AND AGRICULTURAL SYSTEMS

The surface and groundwater resources of the Niouniourou basin with deficits of 40% have a greater impact on a 24% decrease in annual rainfall. The explanation for this difference between the rainfall and hydrological deficit comes from a reduced contribution of groundwater inputs to surface runoff with the decrease in rainfall (Olivry et al. 1998; Mahé et al. 2000). The piezometric level decreases with groundwater reserves and leads to the level of base flows. Indeed, there was no memory effect of the drought on Fresco's groundwater resources as noted in the Sahel by these authors since any increase in rainfall leads to an increase in surface flows. The Fresco region is irrigated by abundant rainfall and spread over two seasons. The area also has a significant vegetation cover that favours infiltration. The relationship between rain, surface water and groundwater is very noticeable. Thus, just like rainfall, average annual flows have been declining in the Fresco region since 1971, but have been in real deficit since 1983. However, these flows increase by 63% over the period 1994-2004 compared to the period 1982-1993 and the drying coefficients decrease by 17% to show groundwater recharge. The increase in flows from 1994 to 2004 has already been noted in the N'zo basin in Kahin du Sassandra (Goula et al. 2006) and in the Senegal basin in Bakel (Hubert et al. 2005). It has also been observed on the coastal rivers Dodo and Néro in the southwestern part of the country, but without any interruption in the decline in rainfall (Fadika. 2012). This variation is not similar to the Sahelian paradox: increased flows while rains are decreasing (Mahé and Paturel. 2009; Mahé et al. 2010). But Niouniourou flows have been declining again since 2005, as has rainfall.

The similarity between rainfall variations and surface runoff at Fresco is also perceived on a seasonal scale. Indeed, rainfall increases during the short rainy season to the detriment of the long rainy season. The consequence is an increase in flows during the second-high water period (October-November).

The water balance shows that REE is the most important fraction of rainfall after infiltration and runoff as reported by Yao (2015) on the Sassandra (Kouakou. 2011) on the Comoé. The rainfall deficit affects runoff (-40%) and infiltration (-33%), which are two important parameters of water resource availability, respectively. The REE decreased much less (-7%) and its proportion in rainfall increased by 9% at the expense of the other two. This shows an increase in temperature and deforestation. The latter causes an increase in solid transport to the lagoon via the Bolo and Niouniourou rivers. Indeed, according to N'guessan et al (2013) 91% of the sands in the Fresco lagoon come from rivers.

The abundance of sub-anguleous and sub-rounded forms of these sands shows their transport over a more or less long distance, i.e. from the watersheds of rivers before being deposited in the lagoon. These sands come mainly from the banks of these rivers where there is less and less vegetation. Reforestation of the banks of these two rivers and the rivers that feed them will therefore help to limit the transport of sediment to the Fresco lagoon. Runoff from Fresco City supplies the lagoon with gravel and pebbles (N'guessan et al... 2013) and certainly other solid elements such as domestic waste due to the increase in bare surfaces with the number of inhabitants. Better waste management in the city of Fresco is necessary to preserve the lagoon ecosystem even if sediment analysis has shown that it is not polluted with heavy metals such as the Ebrié lagoon (Issola et al... 2009). The Fresco lagoon, which is characterized by shallow depths from 0 to 3.5 m (N'guessan et al... 2013), could experience more water depth reduction and limited navigability with solid element transport.

This reduction, combined with the increase in evaporation in the dry season, would favour an increase in the values of physico-chemical parameters such as salinity. Since the ocean's contribution to the lagoon does not decrease but increases with that of sea level. Indeed, with the low water level of the Bolo and Niouniourou rivers, ocean waters completely colonize the lagoon ecosystem (Issola et al... 2008). This could explain the 35.9 g/kg salinity of the Fresco lagoon above the 28 g/kg obtained by Egnankou (2009) cited by Fadika (2018) in the dry season. Measurements at high tide reinforce this high value. However, the salinity of the Gogbey lagoon is higher than that of Grand Lahou, which is 25 g/kg in the dry season (Egnankou. 2009). The latter is the outlet of the Bandama, which has a flow twenty times greater than that of the small coastal rivers that flow into the Fresco lagoon.

However, monthly or seasonal average salinity values for the Fresco lagoon would be even lower since Ama et al (2004) obtain an average salinity of 18 g/kg on the Grand Lahou lagoon for the main dry season. However, the flooding of the Bolo and Niouniourou rivers does not completely desalinate the lagoon, as this high flow is systematically drained towards the Atlantic Ocean, which exerts a very strong suction force. A capture of continental contributions from rivers directly by the Atlantic Ocean is carried out: this is the mouth effect (Issola et al. 2008). Thus, 2/3 of the surface of the Fresco lagoon is very little influenced by rivers. it is an area of low hydrodynamics. There is a certain homogeneity between the lagoon and the ocean when the mouth is open. This relative homogeneity and the ebb and flow of ocean waters within the lagoon are beneficial to the growth of the mangrove swamps present in the Fresco lagoon. In addition, the degree of salinity of the water determines mangrove species (Egnankou. 2009).

The pH of 7.8 in the Fresco lagoon is in the same range as the pH of 7 to 8 obtained in the dry season by Egnankou (2009) and the annual average pH of 7.52 calculated by Issola et al (2008). The latter authors observed the lowest pH of the water in this lagoon in July during the rainy season. However, the average pH shows that it remains basic for most of the year. This confirms the great influence of the sea on the Fresco lagoon. Nonetheless, the nearby lagoon of Grand Lahou does not have basic pH values in the dry season, which vary from 5 to 7 (Egnankou. 2009). This confirms that this estuary-type lagoon is also more influenced by the acidic waters of the Bandama River even in the dry season.

The acid pH of the well water around Frsco and the basic water of the lagoon show that the latter does not seem to affect the former. However, during flood periods, water from the lagoon sometimes enters wells located very close to the shore.

Variations in water resources may affect people's activities and ecosystem functioning in different ways. The decrease in the water level of the lagoon will reduce the quantity of fish and navigability will be reduced. Fishing production will therefore decrease. If salinity increases too much, this will lead to a recomposition of the flora and fauna of the lagoon and a period of adaptation for the living things that depend on it, including humans. The different variations in water resources could therefore lead to a decrease in diversity and a change in the behaviour and habitats of some species.

5.5 OTHER LIVELIHOOD STRATEGIES

At the household level, social, physical, natural and financial assets were considered low in the region. The depletion of the natural capital base is a serious challenge for the livelihood strategies of many households.

The resource stock has decreased due to the nature of the withdrawals and the low replenishment rate. Rivers and lagoon are silted up; the lagoon suffers from the risk of eutrophication at times, and also, from sedimentation. As a result, fishermen now travel longer distances to fish, and quantities and variety have declined in recent years. Other livelihood activities that have been identified and can be considered as strategies include small-scale trade, food processing, the sale of fresh fish and the sale of agricultural products. However, these strategies are hampered or even slowed down in their implementation insofar as the support infrastructure to facilitate the improved use of the region's assets is absent or in deplorable condition. For example, the road network is very bad hence unable to adequately facilitate the easy transport of inputs, agricultural or fishery products to processing or market centres. Electricity coverage remains low in the study area and facilities such as cold storage for fresh fish are absent. Markets that are organised, are rudimentary or basic in terms of trade and market facilities, although the potential is significant.

Communities in the upper basin, which depend mainly on agriculture, whether for food or cash crops (plantations), should benefit from agroforestry. There is potential for reforestation to restore forests. It should be ensured that species are carefully selected to avoid problems of maladaptation to achieve optimal value for use, either as firewood, or for construction equipment. etc.

Crop diversification is a safe strategy to reduce vulnerability due to crop failure or loss due to drought events. However, a rigorous evaluation based on market research to inform the choice of crop varieties will greatly improve farmers' vulnerability. In addition, the introduction of a system for processing staple food crops, with particular attention to manufactured products and their labelling, will undoubtedly make a significant contribution to improving communities' livelihoods. Especially since these products could more easily find markets in big cities, such as Abidjan.

5.6 SUMMARY AND CONCLUSIONS

Based on the perceptions of community members, the results show that sea level rise, severe storms, storm surges, sea surface temperature changes, prolonged droughts and extreme precipitation are the main indicators of climate change impact on the Fresco lagoon landscape. Similarly, forests and mangroves are in rapid decline, as most wood species and mangroves are cut for export and fuelwood. With regard to ecosystem conditions and the supply and use of services, a significant variation in household use and dependence was observed through field surveys. Of the nine (9) main ecosystem supply services (fish catches, building materials, wood, fuelwood, fibre, charcoal, roofing materials, fodder and fodder and medicines) fuelwood was identified as critical by households in communities and its use remains the most widespread.

Almost all respondents considered that other ecosystem services, including soil fertility, aesthetic value, pollination services and recreational sites, were in degrading conditions. The survey results indicate strong population growth associated with overfishing, which is very destructive, sand extraction, and the use of pesticides as the main drivers of change and challenges to the sustainability of the Fresco ecosystem. Thus, the social, physical, natural and financial assets of households were considered low in the region. The sustainable use of natural capital resources presents serious challenges for many households.

6.0 ADAPTATION CAPACITY OF INSTITUTIONS AND NATURAL ECOSYSTEMS

Agrawal (2010) proposes four approaches for better adaptation to climate change: (i) providing meteorological and climate information; (ii) promoting technological intervention that contributes to increasing productivity; (iii) providing financial support to assist in the implementation of these technologies; and (iv) providing leadership in efforts that promote collective action for adaptation. But, it is also essential to stress that one of the most important factors strengthening the adaptive capacity of individuals, households and communities is their access to and control over natural, human, social, physical and financial resources. Access to and control of resources for adaptation varies across countries, communities and even households (CARE International. 2009). In general, they are influenced by external factors such as policies, institutions and power structures; other sources even speak of "political capital" as opposed to natural and human capital. Adaptive capacity may vary over time depending on changes in context and specific hazards (CARE International. 2009).

6.1 INSTITUTIONAL ANALYSIS

For many years, actions have been undertaken to understand the impacts of climate change and how communities could adapt to these different impacts. In view of this situation, it is urgent to analyse the role of institutions and institutional mechanisms in these adaptation processes, particularly at the local levels.

Indeed, local institutions implementing state policies must provide an enabling environment that not only guides development actors in planning and implementing adaptation interventions, but also allows communities, particularly agricultural communities, to adapt to climate change (Berman et al. 2015. Hallegatte et al. 2011. Otieno et al. 2017. Urwin and Jordan. 2008. Zougmoré et al. 2016). However, despite numerous pleas for the importance of institutions for governance systems that help address climate and other challenges, both national and local institutional frameworks are still far from the capacity expectations required.

In Côte d'Ivoire, climate change is also accompanied by many negative effects in all regions. Institutional leadership on climate change is provided by the Ministry of Environment. It is supported in its missions and prerogatives by several other technical ministries through public technical structures, local and international non-governmental organizations, development partners and private sector actors. However, the question arises: what are the institutional responses to the effects of climate change in the country at the local level, particularly in the Fresco lagoon landscape?

6.1.1 NATIONAL INSTITUTIONAL FRAMEWORK

Adaptation to climate change is currently a development challenge for Côte d'Ivoire. Like many climate change reports around the world in recent years, climate adaptation has continued to drive policy actions aimed at creating a more resilient human system with better adaptation mechanisms. Rapid adaptation can reduce economic damage. But slower but effective adaptation will probably amplify it by establishing an appropriate institutional framework with a clear definition of responsibilities, rights and duties and appropriate incentives. In short, it is not enough for adaptation to be slow to be effective. Slow progress in itself is not enough, as it should be used to strengthen institutions and give them the powers and means to carry out their mandates effectively. Understanding adaptation is particularly crucial in developing countries and in sectors such as agriculture, which is particularly vulnerable to climate change (Parry. 2007).

Policies and strategic documents

In 2012, the Ministry of Environment set up a National Program for Greenhouse Gas Mitigation and Adaptation to Climate Change (PNCC). The objective is to ensure that national actors, namely: the Ivorian Government, economic operators, civil society and the population, and all stakeholders, can transform the challenges of climate change into opportunities for sustainable development, thus contributing to improving their living conditions.

In addition, to reflect its commitment to combating the adverse effects of climate change, Côte d'Ivoire has signed several international environmental conventions and agreements (cf. Annex 1) and put in place national laws and regulations (cf. Annex 2). In addition, at the national level, the country has made a real commitment to improve its overall internal environmental protection, climate change and sustainable development framework. Significant efforts have therefore been made with the implementation of multiple programs and actions (see Annex 3). (cf. Annex 3).

The legislative and regulatory framework has also been gradually developed over the years and serves as a compass for taking the environmental dimension into account in the overall and sectoral economic and social development policies. Taking into account all these actions, the country is a key actor in the global governance system for climate change mitigation and adaptation. It thus demonstrates its desire to reduce the carbon footprint of its development through the following actions: (i) give priority to mitigation options; (ii) strengthen the country's resilience to climate change; (iii) ensure coherence between its sectoral policies supported by the strengthening of its mechanism and implementation tools to facilitate the achievement of these objectives and mobilize all necessary means to this end, including financing, both national and international.

However, it should be stressed that the definition of national strategies and policies to better manage the impacts of climate change is by no means a panacea. One of the determining factors is their implementation at all levels, particularly at the level of regions, districts, cities and municipalities in Côte d'Ivoire, which are directly affected by climate change. Thus, the important question is whether these policies at the national level are actually implemented at the local levels?

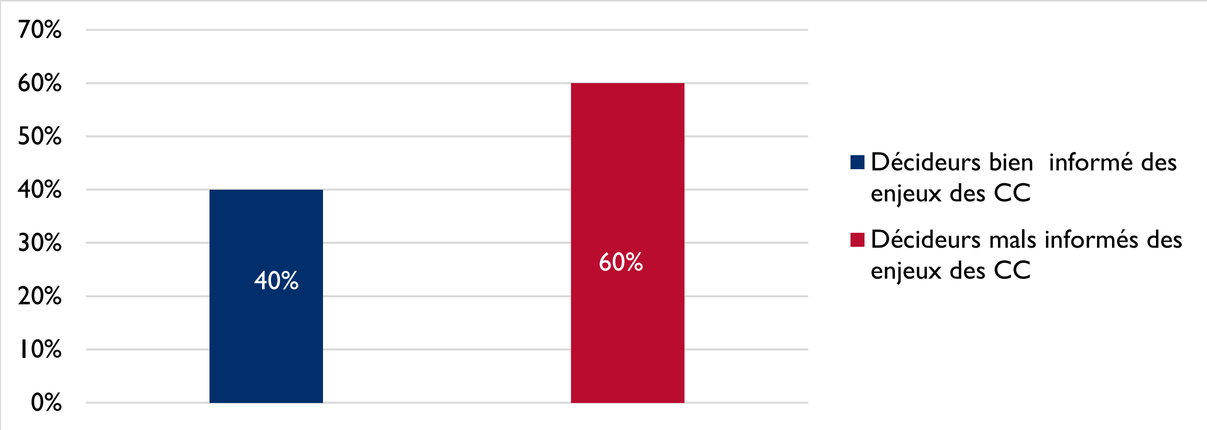
6.1.2 INSTITUTIONS IN THE FRESCO LAGOON LANDSCAPE

It is generally recognized that the capacity of communities and localities to manage the impacts of climate change is closely linked to the capacity of political systems to integrate climate change. by creating a synergy of coherent adaptation actions with other policy areas. Therefore, addressing climate adaptation concerns depends, inter alia, on the ability of political institutions to coordinate and work in traditional sectoral policy areas. the development of procedures, structures and skills to support policy perspectives in areas relevant to climate change adaptation.

The analysis of primary data collected from institutions in the Fresco region highlights the existence of institutions that unfortunately are poorly informed about climate change issues and their implications (direct or indirect) on the way of life of the local population. Indeed. 60% of these institutions are poorly informed about the real issues of climate change and its multiple implications, compared to only 40% who are well informed (Figure 56).

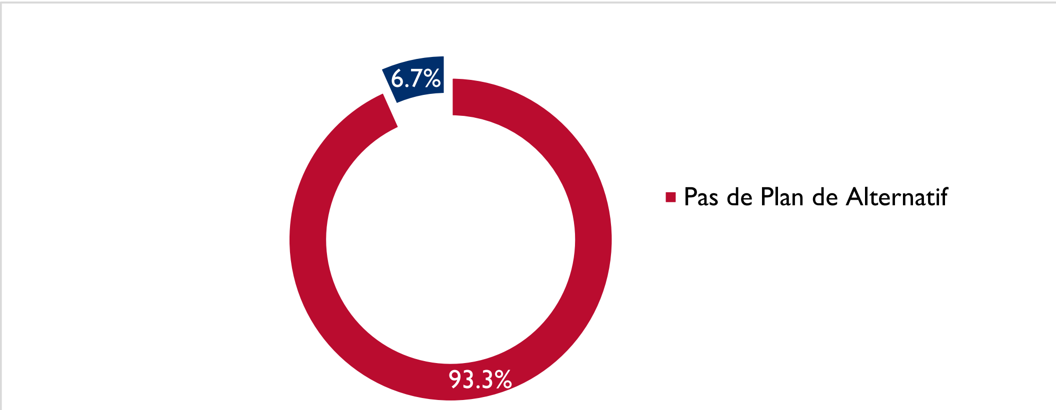
Figure 56: Knowledge of climate change issues by local institutions

In addition, the results show that there is almost no alternative plan in the event of interruption basic



services such as health, education, infrastructure, food, shelter, etc. Indeed, the majority of institutions (93.3%) report that there is no alternative plan in the department, compared to only 6.7% of institutions (Figure 57). For the latter, the existence of this plan is characterized by swift emergency meetings in the event of disasters.

Figure 57: Existence of an alternative plan



The 2005 World Conference on Disaster Reduction in Japan recognized that when governments focus on adopting comprehensive disaster risk reduction strategies, the complementary functions envisaged at the national, municipal and local levels are further strengthened.

In Côte d'Ivoire, there is currently little legislation specifically related to disaster risk management outside the Emergency Response Plan (ORSEC; Decree of 8 August 1979 on the organization of the National Disaster Response Plan). It is a mechanism for coordinating relief operations set up at the national, regional and municipal levels to manage emergencies in the event of natural disasters. This plan provides for a national legal framework for emergency management and makes it possible to mobilize exceptional resources to respond to disasters. There is also the National Platform for Disaster Risk Reduction (NFP-RRC) which was established by a 2012 decree. Its role is to organize and coordinate the implementation of awareness, prevention and response to disasters.

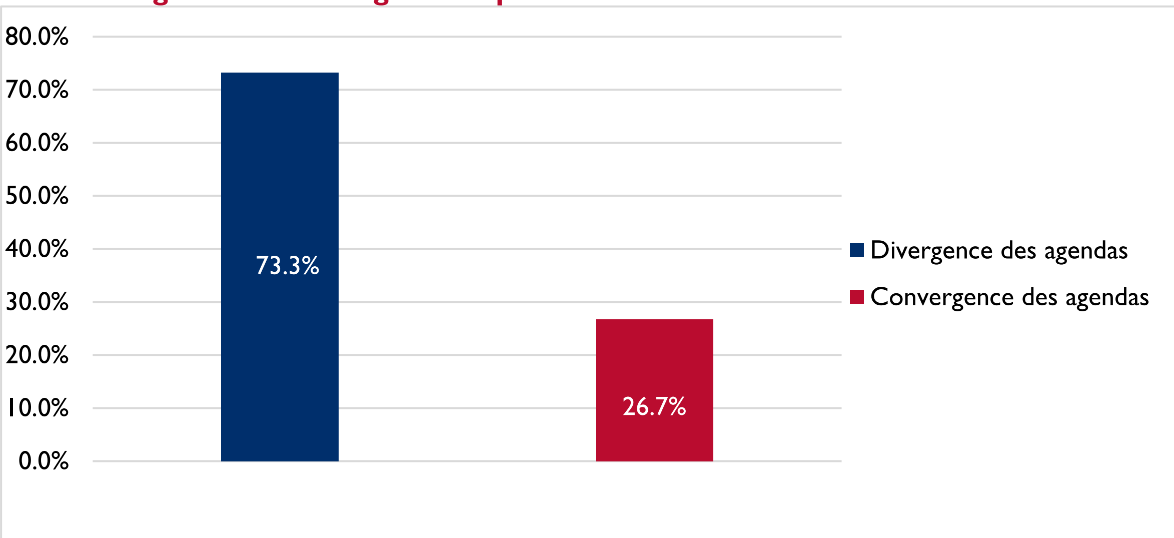
With regard to the locality of Fresco, most institutions (93.3%) report that there are no Early Warning Systems (EWS) in place in the locality. Discussings with authorities at the district did reveal the existence of the ORSEC plan. However, it remains to date non-operational in the Fresco region. Fresco has in fact recorded a marked virtual absence of SAP.

In addition, village committees such as disaster relief committees hardly exist. This weakens the locality's ability to efficiently manage potential crises or disasters - similar to the flooding that occurred in "Zegban" in previous years. Yet crisis or disaster management is important in the emergency response process and allows the community to prepare for the worse. This preparation is done by determining in advance the most appropriate types of responses to the crisis and the most effective mechanisms for implementing them.

We also note the lack of human and financial resources to address climate change and its effects on multiple ecosystems in the locality. In addition, there is lack of an institutional framework for consultation to address priority issues in the region related to climate change, particularly those related to: (i) the destruction of mangroves; (ii) the reduction of fish stocks through the use of chemicals for fisheries; (iii) the risk of flooding of certain inhabited areas; (iv) changes in cropping seasons and risks of food insecurity; (v) threats to public health and education. etc.

The observations point to discrepancies between institutional actors within the locality (Figure 58). Indeed, 73.3% of institutions consider that there are probably differences of opinion and interests between political and administrative actors in the region, compared to only 26.7% who believe otherwise. In addition to the factors of inconsistent planning, these divergences and conflicts of interest between institutional actors hinder efforts to adapt and reduce vulnerability. This situation, leads to inefficiency of action and waste of resources.

Figure 58: Convergence of political and administrative interests



In addition, despite some awareness-raising activities on climate change issues initiated by some key actors in the locality such as SODEFOR, Water and Forests Commission and the municipality, the majority of the population is poorly informed and therefore vulnerable to this phenomenon. With regard to the preservation of forest cover, it appears that despite initiatives for afforestation and restoration of ecosystems, protected areas are being depleted by the population. This is the case of mangroves that are destroyed and/or overexploited by local populations for fuelwood. In addition, forest reserves are inhabited by certain populations with the authorization of SODEFOR. Institutional bodies of the locality are dramatically lacking adequate human and financial resources to clearly address the different dimensions of climate change in local development actions. Apart from the three-year program 2018-2020 of the municipality of Fresco, which unfortunately ignores CC-related issues, the absence of a Communal Development Plan (CDP) once again illustrates the low interest shown in climate change in the locality.

Finally, it should be highlighted that despite national initiatives and policies, existing regulations are rarely implemented and enforced on the ground, i.e. in localities. Better still, local representations of institutional entities are very poorly equipped and lack adequate qualifications to better address CC issues. The low use of research institutions, particularly the results of their work, represents, in addition to the factors mentioned above, another striking feature of the "status quo" in terms of adaptation to climate change in Fresco.

The results presented above are not unique for the locality of Fresco, but corroborate with the findings of work carried out in other parts of Africa (Madzwamuse. 2010; Thondhlana et al. 2015). Europe (Clar et al. 2013) and Latin America (Pramova et al. 2015).

The results indicate that none of the institutions clearly addresses the issue of climate change or deals exclusively with climate in these prerogatives. The institutions present in the locality rather deal with development issues, which, because of their cross-cutting nature, include some actions in this direction. In addition, apart from the accessibility of populations to decision-makers, the non-involvement or inappropriate involvement of institutions and other actors in policy formulation and insufficient coordination in climate action strategies explain: (i) lack of knowledge of existing policies. leading to lack of ownership and limited compliance; (ii) policy planning and implementation decisions that are not informed by research data on local needs and constraints; (iii) available research results on CC issues are rarely consulted by local political actors due to insufficient coordination between policies and research. However, to optimize the use of research results by communities, it would be appropriate for them to be translated into plain language before being transmitted to decision-makers at the local level.

According to recent work, institutional effectiveness in defining adaptation policies can only be achieved when policy development procedures and adaptation strategies are aligned and involve partners at several levels and take into account the needs and constraints of policy makers and rural communities (Cochrane et al. 2016). The limited technical capacity of public institutions, private institutions and communities in Fresco results in inadequate climate adaptation planning and limited access to funding available for climate change impact management (from international partners). This lack of capacity within local public institutions prevents government and political authorities from taking action to implement national climate change planning guidelines at the local level. Biagini et al (2014) points out that capacity building is a very important factor in enabling adaptation at the local level.

In addition to the factors listed above, some authors point out that policy ineffectiveness also depends on limited budget allocations (Hepworth. 2010; Rwakakamba. 2009) through insufficient participation and linkages between actors (Friis-Hansen et al. 2013; Madzwamuse 2010 and Orindi. 2013).

These conclusions are verified by our results, which reveal that the lack of financial resources and synergy of actions between political actors is also responsible for the institutional gap in the locality. Our results reveal that a set of contextual factors limit the effective implementation of climate change adaptation policies in the Fresco region. Therefore, addressing these institutional challenges requires a multi-stakeholder and multi-scale approach. This may require a renewed commitment by national authorities to the principles of decentralization.

In addition, inefficiency in policy implementation at the national level leads to lack of empowerment strategies at the local level. The overlapping missions of national bodies in charge of environmental issues, the legal vacuum of laws and regulations related to CCs. the absence of genuine national frameworks for consultation of environmental protection actors. conflicts of interest. etc. are all factors at the national level that characterise institutional inefficiency and have an impact at the local level.

As regards to the lack of operational early warning systems (EWS) or at least EWS in the locality (despite the high prevalence of exposure of the region to natural hazards), the institutional gap mentioned above would, undeniably, be the main reason.

Education

According to Sankaré and Aka (2016), there are 59 primary schools in the Fresco region, including 3 private schools. Out of 300 available classes. 100 are built of rudimentary materials due to lack of financing. It is the populations themselves, the majority of whom are farmers, who work for the well-being of the children. Fresco remains a disaster prone area due to lack of viable projects for schools without water pumps. Today, there is only one nursery school, which is the foundation for the quest for knowledge, although 27 nursery schools were planned on paper. The school canteen is a key element in the functioning of the school system and Fresco has 24 at the basic school level. However, it should be noted that the ratio has been reduced in contrast to previous years (3 allocations reduced in a single year today). At the secondary level, 3 schools stand out with a single public high school built since 1978 with a capacity of 2500 students for 60 teachers. Local authorities estimate the enrolment rate at 80%. Socio-cultural organization and education contribute to the improvement in economic life.

Education and awareness are important factors in making informed decisions. They play a key role in building community capacity to adapt and mitigate the effects of climate change and equip women and men with the knowledge necessary to adopt sustainable and adapted lifestyles.

The region's education services are relatively satisfactory with primary and/or secondary schools in almost all localities. The representation of the Ministry of National Education in charge of the region's education policy implements all the necessary strategies for the education of the population. However, it is noted with regret that there are no predefined climate change adaptation policies in the action matrix of educational institutions in the region: the absence of measures to protect educational infrastructure from climate change, which could minimize the risks, particularly those associated with the costs of damage caused by bad weather.

Adaptation in the sector would allow for better risk assessment in decision-making regarding the location of schools and improved building design and maintenance to better withstand severe weather events (DAS. 2008). Capacity building for actors in the education sector to address climate change issues in the region is necessary for a better policy of adaptation to CCs. Similarly, the integration of climate change into training curricula (kindergarten, primary and secondary) is also a good way for populations to be trained and informed about the harmful effects of this serious phenomenon that increases their vulnerability.

Sanitation

In the same way that the growing number of the population (natural growth and immigration) accelerates the demand for food products, including fish products, fuelwood, etc., it is equally the cause of an increasing volume of pollution of various kinds. Indeed, urban development and the inadequacy of sanitation networks and the lack of wastewater treatment are all aggravating factors in the vulnerability of populations in cities. Fresco has a rainwater drainage network along the main road that runs through the city in two directions. However, it is worth considering whether this network is well sized in relation to possible floods in the city... In relation to wastewater, there is no dedicated network.

Other sources of environmental problems to be associated with urban development are: (i) growing and wild household waste; (ii) pollution; loss of quality and health of aquatic environments; (iii) pollution and land degradation; (iv) increasing use of chemical fertilizers in plantations and insufficient control of technologies for the use of these hazardous products that expose people to health problems; (v) erosion of biological diversity. In the case of Fresco, what could further aggravate pollution issues is that we are in a watershed context and that the city and its lagoon are the receptacle for all pollution since they are located downstream.

Strengths and Access to Financial and Social Capital

In Fresco, intra-community links are very strong (existence of associations and mutual aid societies). In addition, there are a few cooperatives that are very active in processing. EKLOHEWOU". The United Sisters' Association. Women are very interested in this food crop processing sector, but the actors for financing are often lacking. Indeed, lack of a dynamic microcredit system to support small farmers is deplored. This lack of opportunities to support households increases their vulnerability, especially since their financial assets are considered weak.

Tourism should have a good place in the socio-economic activities in the lagoon site of Fresco and be a factor of development. But the situation is far from being so; although, there is no shortage of natural sites: sea. lagoon. sandy coasts with rocky aspects in places, the mouth during the opening period, bays and capes, Ramsar site etc. Lack of good quality hotel accommodation also remains a serious handicap to encourage the development of this sector.

Lack of quality information and data is a constraint to policy making and support for the sector. It is important to have relevant indicators such as: food security, jobs, local wealth creation (value added to production, value added, marketing), investments, contribution to public and local finances, contribution to the social sustainability of the sector to better manage the landscape. Finally, lack of collaboration between Institutions and civil society organisations remains a factor to be looked at. The challenge here is that of administrative and institutional governance, which is due to lack collaboration with civil societies in the implementation of projects for development. Many of the constraints that would have to be overcome to alleviate poverty are obstacles to the integrated management of the Fresco landscape. These constraints are essentially: insufficient social inclusion, insufficient gender integration, insufficient development, insufficient youth involvement, insufficient subsidies to local populations.

Awareness of climate change

In Côte d'Ivoire, however, NGOs and association remains active in advocacy, information, awareness-raising and communication on environmental issues. Agricultural cooperatives seem to be better organized, but their objective remains production and marketing; hence there are real opportunities to integrate and put into practice climate-smart agriculture. Environmental aspects are not taken into account at this level, but sustainable development requires it today.

Local adaptation strategies

Threats to natural capital are serious challenges to the coping strategies of many households. Indeed, the linkages and interactions between climate change and anthropogenic changes such as deforestation of mangroves and other coastal ecosystems could have profound impacts on regional socio-economic development, including local livelihood strategies, especially as the provision of ecosystem services and agricultural production have declined recently.

Communities surveyed distinguish four climate seasons in the year. With regard to climate variability, farmers agree that rainfall varies significantly in the Fresco region. Opinions are unanimous on the decrease in rainfall and its poor distribution. This results in an uncertain beginning and end of the rainy seasons. followed by the persistence of rainfall breaks during the rainy season. They also note that the increase in the frequency and intensity of droughts, which is related to the increase in temperatures, is likely to permanently weaken some plants, in particular by opening the way for parasitic attacks. Storms and other wind-related phenomena were frequently cited as the hazard that could threaten the lives of people in the barrier beach. However, they deplore the fact that they do not receive official information on the prevention of these hazards. Flood experience seems to be the most important factor related to increased risk perception. The closer the community is to a watercourse, the higher the perception of flood risk. Periods of high temperatures are perceived by the population which they explain as being the result of heavy deforestation suffered by the Fresco region since the 70s when the State's policy was based on the production of cocoa. Such a context has therefore led to periods of heat waves and/or long periods of drought as observed since the 80s.

Other livelihood activities that have been identified and can be considered as coping strategies include small-scale trade, food processing, the sale of fresh fish and the sale of agricultural products.

The socio-economic consequences observed by the populations in terms of rainfall variability are a drastic reduction in cocoa yields, which leads to opting for other perennial crops such as rubber, oil palm (example of Dassioko, Dahiri and Okromodou). There are examples of agricultural diversification where cash crops almost take precedence over food crops.

At the level of extreme events, populations are aware of the risk and are inclined to adopt protective behaviours. Thus, the populations of the Fresco barrier beach, most of whom are of Ghanaian origin, would be willing to relocate elsewhere because of a perception of the increased risk of marine flooding that threatens their habitat and safety. But, moving foreign populations, would lead to land implications, especially where they would be relocated to.

To cope with the floods, some residents of Zégban. faced with severe damage, are more likely to put in place preventive measures, including moving to a more secure location.

Faced with high temperature, populations are advocating reforestation, and agroforestry in order to preserve the health of forests and ensure their survival as a large natural reservoir for improving their living conditions. For preserving forests means preserving the ecosystem services from which people derive enormous resources for their survival.

In order to be able to live and develop in a changing environment (drought, flood, high winds, etc.), plants have acquired a number of provisions relating essentially to morphology, reproduction and anatomy. Mangroves are not immune to this dynamic either. Thus, mangrove species have put in place measures to enable them colonize unstable and changing environments. They have adopted specialized aerial roots (*rhizophores in Rhizophora racemosa and pneumatophores in Avicennia germinans)*. These root systems not only provide a good support on the muddy substrate, but also allow the plants to perform their breathing function.

By their mode of reproduction which is done by viviparity, mangrove species have adapted to life in the intertidal zone subject to the daily influence of the tides. Under these conditions, the seed germinates on the tree and gives birth to a seedling that. at maturity. detaches itself from the tree fixes itself in the mud subjected to submersion and continues its growth by developing leaves. They colonize the new lands newly retained on the waterfront by the reticulated root structure and help to stabilize them.

To survive in the intertidal zone and cope with sea level rise, mangrove species have put in place adaptive mechanisms for sediment retention or landings as seen in the creation of land on the waterfront where they are located. Indeed, the mangrove forest is a natural means of creating conditions to counter the destructive forces of waves and high winds and thus to fight against erosion. The stilt roots of the Rhizophora and the pneumatophores of the Avicennia intertwine and form an inextricable network that, by stopping alluvial deposits and debris carried by rivers, continuously encroaches on the sea or lagoon by the new "lands" created on the free side of the water. The gilt-edged aspects of roots are real soil traps (Navalkar. 1961. cited by Egnankou. 2018). However, it must be recognized that all these forms of adaptation developed by pallet trucks have their limits. Indeed, according to the IPCC (1995), climate change is accompanied by various consequences, such as disruption of the water cycle, threat of disappearance of certain coastal areas, in particular deltas, mangroves, coral reefs and beaches, and an increase in the frequency and intensity of natural disasters of climate origin (droughts, floods, storms, cyclones). In addition, global and regional climate change is leading to rising sea levels and variations in rainfall, leading to increased water salinity during the dry season and the presence of coarse sediments during the rainy season.

6.2 SUMMARY AND CONCLUSIONS

The analysis of the role of local institutions in the process of adaptation to climate change has enabled us to identify three (3) key facts and their implications. First, the results point out lack of implementation of national policies at the local level, thus creating an institutional gap. Secondly, lack of coordination of actions between local institutions must be strongly looked at and promoted. And finally, the non-integration of adaptation into local development policies.

On the basis of the above, the following recommendations deserve to be taken into account for a better integration of climate change adaptation at the local level. Local institutions should carry out the following actions:

- translate national policies, programs and strategies related to climate change at the local level;
- integrate climate change and its implications into local development policies;
- seek external assistance and expertise for the elaboration of the Communal Development Plan (CDP) with particular emphasis on taking adaptation measures into account;
- improve and strengthen the synergy of actions between entities at the local level;
- seek capacity building on climate change issues;
- establish early warning systems to reduce the effects of climate change and other risks;
- disseminate and make more accessible the early warning message on the effects of climate change and other risks (with internet. administration. community radio. SMS. max. channels etc.);

- inform. educate and raise awareness of the negative effects of climate change.

7.0 OVERALL VULNERABILITY OF THE FRESHWATER LAGOON LANDSCAPE

In order to assess the overall vulnerability of the Fresco lagoon landscape, a vulnerability index has been developed (Adger 2006; IPCC 2007; CARE International. 2009; Weis et al. 2016; (Figure 59)

Exposure, in the HSE methodological framework, is documented through climate analysis, through sub-components related to climate variability and projections. For climate variability, four (4) results have caught our attention: i) Fresco has experienced a warming of 0.5°C over the past 50 years; ii) a decreasing trend in precipitation since the 80s; iii) an average sea level rise of an average of 19 cm between 1961-2010; and iv) an increasing trend in flood frequencies, dry periods and storms. As for climate projections, we have retained: i) an increase in average temperatures over the region to 1.0°C in 2050. 1.5°C in 2100 for scenario 4.5 on the one hand and up to 2.0°C in 2050. 4.0°C for scenario 8.5 on the other hand; ii). For rainfall, seasonal precipitation is expected to decrease associated with a change in rainfall distribution; iii) sea level rise of +0.26 m for scenario 4.5 to +0.63 m for scenario 8.5 by 2100 and. iv) finally, compared to extreme events, the frequency and intensity of extreme events is expected to increase.

If the three (3) Fresco zones are rated 4/5 on the vulnerability scale to assess exposure to climate change in relation to the above results, Zone 1 will see its rating increased from 4 to 5 because it is simply facing the ocean and remains the only one in relation to the other two (2) to suffer sea level rise on the one hand and on the other hand to record the consequences resulting from it, particularly on the coastal cordon occupied by fishing communities. and also the lagoon with its mangroves. Highly sensitive Ramsar site.

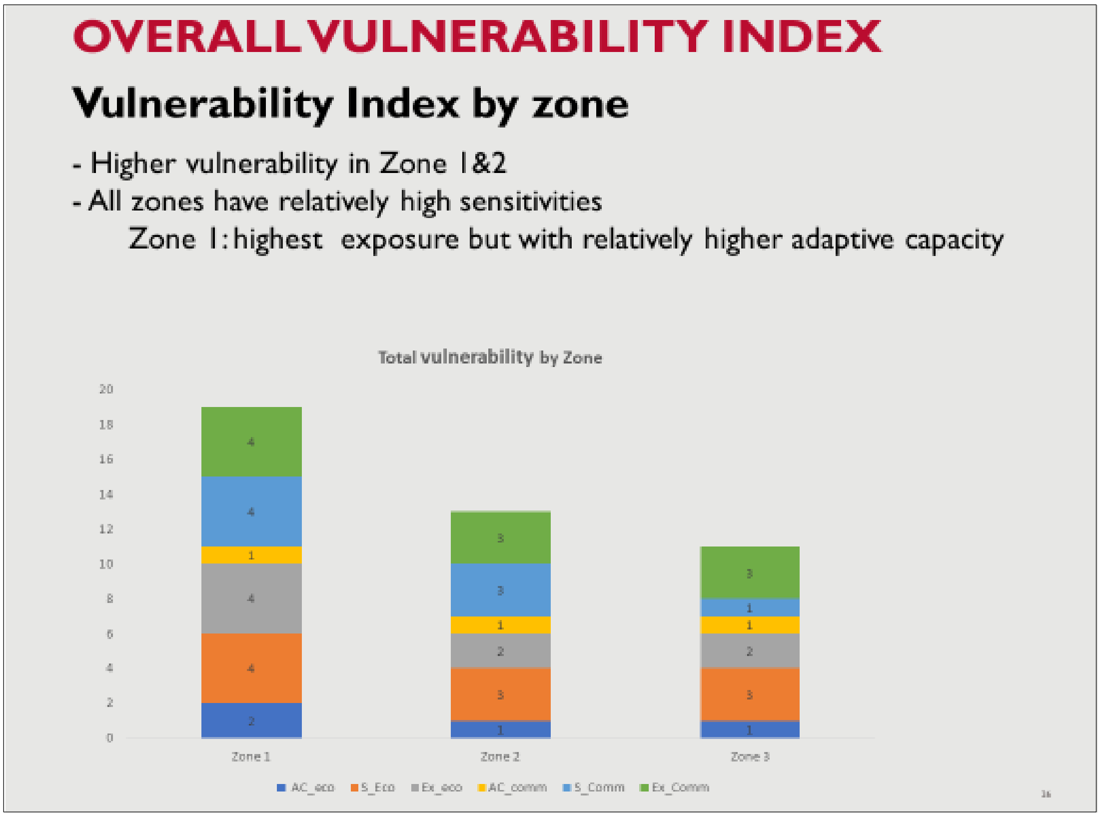
The sensitivity of socio-ecological systems is assessed by taking into account the risk assessment according to populations (surveys) where only the responses to the highest risk are at stake, knowing that the weighted factors are essentially related to the drivers and status of non-supply ecosystem services (cultural support and regulation). Certainly, communities are unanimous on the pressures exerted by both drivers and the advanced state of degradation of non-supply ecosystem services.

In addition to the opinion of the communities, it is necessary to take into account climate hazards per zone. This makes it possible to recall a particularity of sensitivity. Sensitivity is the degree to which a community is affected by climate stresses. A community dependent on rainfed agriculture will be much more sensitive than a community whose main livelihood is mining (CARE International, 2009). Fresco communities are essentially farming and fishing, while in zones 2 and 3 the same climate hazards or stresses are recorded (floods. prolonged drought. deforestation and bush fires), in zone 1 there is much more (floods, prolonged drought, sea level rise, storm surges, sea surface temperature increase, deforestation in both continental forests and mangroves, and bush fires). **Zone 1 differs from the other zones and its score is estimated at 5 (the highest possible score) so zones 2 and 3 are estimated 3/5 and 4/5 respectively**. Deforestation phenomena are estimated to be significantly higher upstream (zone 3) than in the central zone (zone 2); deforestation affects not only fields where cocoa plantations are the first victims (Okomoudro zone) but also other parts of the catchment areas. According to people in Okoumodro. "the disappearance of forests to the detriment of plantations has exposed cocoa plants to solar radiation; we are no longer witnessing the agro-forestry that protected young cocoa plants". Finally, there is the sensitivity recorded by mangroves, threats to water resources and changes in land use and occupation. where it is easy to see that even though communities are increasingly turning to cash crops, this is at the expense of the forest cover. (Table 17b).

Adaptability, within the framework of the HSE methodology, is only documented by institutional analysis. We had already pointed out this inadequacy, because the capacity for adaptation is more global than that. Indeed, communities also have adaptive capacities insofar as they have access to or control over natural, human, social, physical and financial resources. On the other hand, it is the responsibility of institutions (Office of the Mayor, Local and State authorities, through various decentralized services to define the political context of intervention. Considering the results of the institutional analysis on the one hand and the adaptive capacity of communities on the other, which is generally low even if assets exist, they remain poorly exploited and to a lesser extent, not with a view to sustainable development... Good news remains shared within the institutional analysis giving that awareness actions on climate change issues have been noted in the Fresco area. This contributes to a better awareness of communities and institutions about the risks involved, but also about what can be done to implement corrective measures.

With regard to the different scores recorded, the following ranking was proposed: the vulnerability index shows that zone 1 (which covers the first 10 kilometres around Fresco), which includes the Fresco lagoon, remains the most vulnerable area with regard to the occurrence of climate hazards (Figure 60), pressure on resources and the responses to the scale of the problems. Indeed, this area is credited with a value of 5/5. Zone 2 (which concerns the band between 11 and 20 kilometres north of Fresco) and zone 3 (which concerns the stretch above 20 kilometres) are credited with 4/5 on the vulnerability scale (Figure 60). However, a slight weighting could benefit Zone 1 as all the institutions are located there in Fresco; in the event of a disaster, it has a higher response capacity than the other two zones. In the event of a disaster, in zones 2 and 3, the institutions based in Fresco will certainly intervene, but it must be borne in mind that there is a distance to be covered between the place of the disaster and that of the institutions before any intervention. To this can be added the condition of road networks and other parameters that may slow down the speed at which institutions should intervene.

Figure 60: Synthesis of results of the overall vulnerability of the Fresco lagoon landscape



8.0 RECOMMENDED ADAPTATION OPTIONS

Given the diversity of challenges and constraints facing the Fresco lagoon landscape, the vulnerability assessment proposed some options to support sustainable alternative livelihoods and maintain the capacity for regeneration and consequently the ability to provide services expected by human populations from all local ecosystems and improve community resilience. Forest and mangrove restoration, improved extension services, input support programs, strengthening food and fish processing and storage infrastructure and reducing resource consumption through simple technologies such as mud stoves for households and fish processors.

Adaptation options that reduce vulnerability to climate change are the result of the validation workshop on vulnerability assessment of the Fresco lagoon landscape. These adaptation options are divided into two broad categories:

i. Those from the point of scientific experts divided into three working groups (1. Climate analysis and expected climate impacts on populations and ecosystems; 2. Vulnerability of ecosystems, including mangroves. and livelihoods; 3. Institutions); and

ii. Those formulated by community representatives in the form of public consultation, always during the same event.

The list below, outlines the options identified by the experts:

1. Sensitize and train decision-makers in decentralized technical and administrative services on climate change;
2. Establish an early warning system on the effects of climate change and other risks;
3. Disseminate and make more accessible the early warning message on the effects of climate change and other risks (internet, administrative, community radio, SMS, max channels etc.);
4. Maintain and increase the density of hydrological and climatological observation networks;
5. Integrate climate change into educational programs (primary, high school);
6. Improve and strengthen the synergy of actions between entities at the local level;
7. Elaborate a local development plan integrating climate change;
8. Improve the value chain by improving technologies;
9. Popularize renewable energies at a lower cost;
10. Promote improved stoves;
11. Set up social networks through credits, savings etc.;
12. Popularize research results on forest species;
13. Report any unexplained changes in the ecosystem;
14. Maintain the open pass permanently to ensure the operation of the lagoon;
15. Strengthen monitoring of all human activities in river basins;
16. Involve the population in the search for solutions;
17. Use plain language that is understandable to the population to explain and communicate more clearly on the issue of climate change;

18. Translate the law into communal and community regulations;

19. Improve domestic waste management;

20. Establish a Local Development Plan, articulating and clarifying the Sustainable Development Objectives (SDOs) for Fresco and include a Local CC Adaptation Plan that will contribute to solving local governance problems related to climate change and translate into concrete actions Cote d'Ivoire's commitments to the implementation of the United Nations Framework Convention on Climate Change (UNFCCC). This local development plan will also provide an opportunity to implement at the local level the Abidjan Convention, the Ramsar Convention on Wetlands, the Convention on Biological Diversity and the CITES Convention.

Table 23 below summarizes the adaptation options proposed by community representatives by theme.

Table 23: Synthesis of adaptation options proposed by the communities

Themes	Adaptation options
Climate risks	• Communicate messages (community radio, traditional leader, community leader, etc.) in local languages on climate risks; • Avoid living in high-risk areas (lowlands); • Distribute assistance equitably among victims in the event of a disaster; • Strengthen surveillance more closely in order to enable the Office of the Mayor to prevent the construction of houses in high-risk areas; • Mapping floodplains and making scientific products available to the Office of the Mayor; • Create a channel at the inlet that will be permanently open; • Set up an early warning system and ensure the correct dissemination of the messages that will be issued from the system.
Forests	• Conduct awareness campaigns; • Carry out reforestation campaigns with species adapted to the terroir; • Carry out a massive reforestation in the city of Fresco; • Promote agroforestry, especially in cocoa plantations, because this crop thrives better under shade; • Regulate the use of herbicides; • Combat poaching; • Prohibit bushfires; • Strengthen and improve forest monitoring; • Promote the use of LPG for cooking; • Promote the use of improved stoves; • Promote game farming (for bushmeat); • Promote waste recovery (biogas).
Mangroves	• Organize mangrove reforestation campaigns; • Protect the mangrove swamp (no more cutting); • Prohibition of illegal fishing (mesh size of nets. toxic products); • Promote aquaculture and fish farming; • Create a protective belt around mangroves; • Keep the pass open at the inlet; • Create an oversight committee; • Use habits and customs to protect mangroves; • Strengthen community involvement in the fight to protect mangroves; • Continue efforts to raise awareness of the importance of mangroves for fisheries resources; • Create income-generating activities for the youth.
Institutions	• Improve communication between institutions and populations; • Improve community involvement;

Themes	Adaptation options
	• - Create a framework for dialogue on climate change at the local level; • Provide the town hall with logistical and financial resources for monitoring the lagoon; • Apply appropriate sanctions against all offenders; • Improve the involvement of the traditional Chiefdom for stricter compliance with regulations; • Promote improved stoves in the fishing village; • Encourage the practice of agroforestry.

In general, the challenges remain diverse and varied both for the Government and for its technical and financial partners in the implementation of development policy through programs and projects. The proposed adaptation solutions and measures are both technical, institutional and local knowledge. To this end, the implementation of adaptation options at the local level cannot be disconnected from ongoing initiatives at the national level to optimize actions. As a matter of fact, the challenge would then be to identify implementation bridges in order to achieve transformational adaptation with the most sustainable gains possible. Sustained lobbying efforts by national authorities as well as technical and financial partners should not be excluded from this process. For example: the issue of agroforestry has been raised both by communities and experts and there is an opportunity to have this issue addressed by both the Ministries responsible for Agriculture and Water and Forestry...

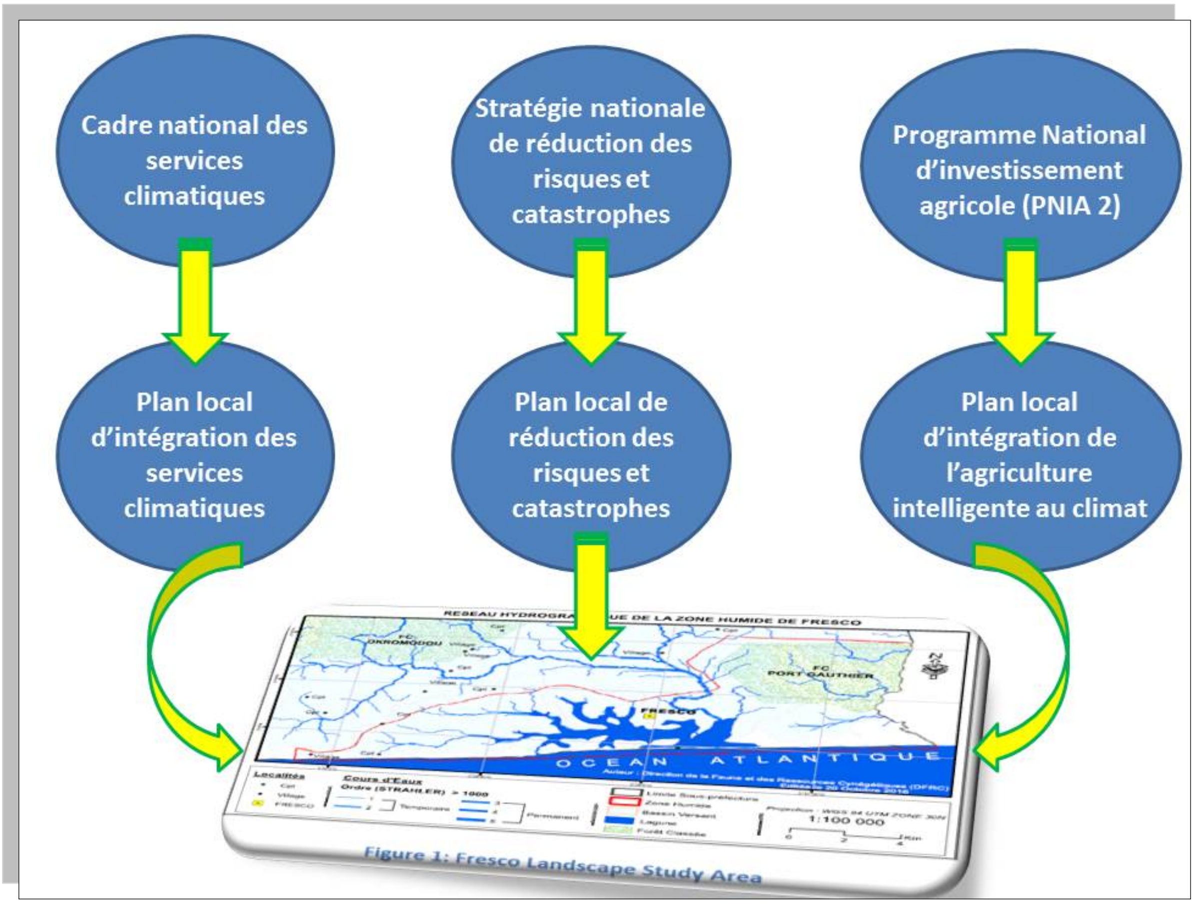
The Fresco area is not one of the "hot spots" of the National Coastal Protection Plan of Côte d'Ivoire. It should be noted that "hot spots" are determined on the basis of their vulnerability to coastal risks, particularly coastal erosion. However, the validation workshop of the survey on the vulnerability to climate change of the Fresco lagoon landscape showed that the effects of climate change are perceptible at all levels. It also made it possible to make a link with the WACA Côte d'Ivoire program. Another bridge for dialogue would be the synergy to be developed between climate services (SODEXAM), smart agriculture in the face of climate and risk and disaster management policy. The philosophy behind it would be to facilitate access to climate information. But also, it should be used in the daily lives of communities. Ideally, Fresco should have strategic documents (such as the Municipal Development Plan) in which these elements will be integrated (Figure 61).

What confirms our position of complementarity and synergy between the various initiatives is that five (5) priority themes have been identified by the World Meteorological Organization in the context of climate services, namely: water resources, agriculture and food security, natural disaster reduction, health and energy. Indeed, the main objective of WCMC is *to "optimize the management of risks associated with climate variability and change and promote adaptation to climate change through the production of scientifically based climate information and predictions and their integration into global, regional and national planning, policy development and implementation processes*"[2].

NMHSs (National Meteorological and Hydrological Services) are responsible for the implementation of climate services at the national level. You will agree that producing climate services for natural disaster reduction complements the implementation of the risk and disaster reduction strategy (guidelines arising from the Sendaï framework); the same is true for climate services and the agricultural sector (smart agriculture in the face of climate change) for better adaptation to climate change. To this end, climate information and services will be used as inputs in the same way as many others. Moreover, since the international as well as national context is dominated by the dual issue of the implementation of the Paris Agreement and the objectives of sustainable development (SDOs). All our efforts must contribute to their achievement.

[2] Troisième Conférence mondiale sur le climat

Figure 61: Coherence of actions and synergies to be developed between national and local policies



Finally, all these initiatives will be supported and accompanied by capacity building. Indeed, according to Miller et al (2014). "the extremely weak capacity of local institutions could be strengthened by initiatives to increase their capacity to manage information and knowledge to assess and prioritize climate risks; improve planning to enhance flexibility and innovation in response to climate trends and shocks; strengthen the capacity to respond to the changing needs of communities through increased participation; strengthen accountability and redress power imbalances".

9.0 GENERAL CONCLUSION

There are two main categories of threats to the Fresco landscape: direct and indirect. The first threats include changes in local land use patterns and land cover. threats to ecosystem services. eutrophication and pollution. elimination of species and/or introduction of invasive species and climate change, the manifestations of which are already being felt and experienced by communities. As for indirect threats, we note political and social demographic aspects (governance, institutional framework) and the economy.

The water resources of the Fresco region are of two types: surface water composed of rivers and lagoon and groundwater mainly in the crystalline basement collected by drilling. These resources are subject to high interannual and seasonal variability in rainfall. Annual rainfall amounts are 24% below average over the period 1983-2017. Surface flows to the lagoon and the volumes of water mobilized by aquifers that can recharge them decrease by 40% over the same period. During this period of rainfall deficit, the contribution to the annual total of the long rainy season gradually decreases in favour of the short rainy season and the long dry season. This variation is more marked from the decade 2000 onwards, reaching more than 10%. Runoff therefore increases sharply during the second-high water period (October-November) and slightly during the main dry season (March-April).

However, during this deficit period, flows increased by 63% over the period and groundwater recharge during the 1994-2004 phase compared to the 1983-1993 phase. The water balance shows that in addition to runoff, infiltration has decreased by 33% over the period 1982-2016. River flows and groundwater supplies leading to the lagoon are directly sensitive or reflect this variability in rainfall with a lag of one or more years. It would be interesting to have the temporal variations in the water levels of the lagoon, sea and rivers at our disposal to be able to carry out a better assessment of resources in a variable and changing climate context. This requires the instrumentation of watercourses in order to permanently assess the flow of rivers and streams, but also the physico-chemical quality of water and traditional meteorological parameters. Because any adaptation to climate change begins with monitoring. and monitoring through a policy of collecting scientific data in accordance with the international standards required in this area. Today, measuring stations such as thalimedes allow the collection of all these data required for monitoring the quality of water resources. This surface water data collection network will be coupled with a network of piezometers to monitor groundwater resources.

Changes in land use and occupancy, where it is easy to notice that even if communities are increasingly turning to plantation crops, this is at the expense of forest cover. Deforested mangroves are over-exploited for traditional uses such as construction, firewood, etc. Such unsustainable use of resources significantly reduces the ability to support the basic socio-economic needs of rural populations. With the multiplication of pressure factors and withdrawals from forests that are constantly decreasing; forests have decreased from 419.44 km2 in 1990 to 215.52 km2 in 2017; plantations on the other hand have increased from 191.94 km2 to 343.24 km2 over the same period.

The results indicate that despite the presence of several institutions in the locality and the region's exposure to the negative effects of climate change, a concrete institutional response is at a very early stage. Indeed. The results reveal: (i) lack of implementation of national policies at the local level; (ii) lack of coordination of actions between local institutions and (iii) the non-integration of adaptation into local development policies. To this, we must add the low capacity (financial, human, technical, material, etc.) for institutional adaptation, which is still limited by insufficient coordination between national and local institutions and communities.

Results from household surveys show, extreme events (sea level rise, severe storms, storm surges, sea surface temperature changes, prolonged droughts and extreme precipitation) are the main indicators of the impact of climate change on the Fresco lagoon landscape. Similarly, forests and mangroves are in rapid decline, as most wood species and mangroves are cut for export and fuelwood. With regard to ecosystem conditions, especially in relation to the supply and use of services, a significant variation in household use and dependence has been observed. Of the nine (9) main ecosystem supply services (fishing, building materials, wood, fuelwood, fibre, charcoal, roofing materials, fodder and medicines) identified as critical by households in communities, fuelwood remains the most widespread. Almost all respondents in the Fresco Lagoon landscape considered that other ecosystem services, including soil fertility, aesthetic value, pollination services and recreational sites, were in degrading conditions. The results indicate strong population growth associated with overfishing, which is very destructive, sand extraction, and the use of pesticides as the main drivers of change and challenges to the sustainability of the Fresco ecosystem. Thus, the social, physical, natural and financial assets of households were considered low in the region. The sustainable use of natural capital resources presents serious challenges for many households.

Adaptive capacity would be better strengthened by facilitating institutional linkages and coordinating responses at multiple levels across all borders of local institutions. Also, the integration of climate change adaptation into the municipal development plan is a necessity if a better adaptation process is to be achieved.

RÉFÉRENCES

Abe J.. Affian K.. 1993. Morphology and Tourist infrastructures of the Ivorian Coast. P. P. WONG (ed.) Tourism Vs Environment: The Case for Coastal Areas.. *Kluwer Academic Publishers*. Printed in the Netherlands. pp. 99-108

Abe J.. Kaba N.. 1998. Problems and Management Strategies of the Ivorian Coastal Zone.In Chidi Ibe*: Perspectives in Integrated Coastal Management in the Gulf of Guinea. Ed. CEDA*; pp. 37-47.

Abe J.. Kaba N. 1997. Côte d'Ivoire : Profil environnemental de la zone côtière. Rap. ONUDI-FEM. pp151.

Abe J.. 2000. Quelques aspects socio-économiques et environnementaux liés à la vulnérabilité du littoral ivoirien aux changements climatiques et à l'élévation du niveau de la mer. *Doc. Projet GEF/2200-97-51 ; UNFCCC.* 58 p.

Abe J.. Kouassi M.. Ibo J.. N'guessan N.. Kouadio A.. N'goran N.. Kaba N. (2000). Cote d'Ivoire coastal zone phase 1: integrated environmental problem analysis. Global Environment Facility. MSP Sub-Saharan Africa Project (GF/6010–0016).

Adger W. N. 2006. Vulnerability. Global Environmental Change 16:268–281

Agrawal A.. 2010. Local institutions and adaptation to climate change. In: Mearns. R.. Norton. N. (Eds.). Social Dimensions of Climate Change: Equity and Vulnerability in a Warming World. New Frontiers of Social Policy. The World Bank. Washington D.C

Akoi. K.. 2004. Fishers and the West African manatee in the Fresco lagoon complex. Cote d'Ivoire. Common property. conflict and conservation. PhD thesis. University of Kent at Canterbury. Kent. UK.

Ama A. A.. Kouassi A. M.. Dosso M. Joanny T. G et Tiecoura K.. 2004. Suivi annuel de la contamination bactérienne des eaux de surface de la lagune de Grand-Lahou. Côte d'Ivoire. *Colloque International « TERRE et EAU » Annaba. 21. 22 & 23 Novembre 2004* : 4p.

Antwi E. K.. Boakye-Danquah J.. Owusu A. B.. Loh S. K.. Mensah R.. Boafo Y. A.. Apronti P. T.. 2015. Community vulnerability assessment index for flood prone savannah agro-ecological zone: a case study of Wa West District. Ghana. Weather and Climate Extremes. 10. 56-69.

Assani A. A. 1999. Variabilité temporelle et persistance des épisodes secs en saison des pluies à Lubumbashi (Congo-Kinshasa). *Sécheresse 10 (1)*: 45-53.

Baptista S.. Brottem L.. de Sherbinin A.. Edquist M.. Fischer A.. Levy M.. Schnarr E.. Simon C.. Sundareshwar. P.V.. Trzaska S.. 2013. *Background Paper for the ARCC West Africa Regional Climate Change Vulnerability Assessment*. USAID. Les lecteurs intéressés sont invités à consulter le document complet sur http://community.eldis.org/ARCC/.

Berman. R.J.. Quinn. C.H.. Paavola. J.. 2015. Identifying drivers of household coping strategies to multiple climatic hazards in Western Uganda: implications for adapting to future climate change. Clim. Dev. 7 (1).

Biagini. B.. Bierbaum. R.. Stults. M.. et al.. 2014. A typology of adaptation actions: aglobal look at climate adaptation actions financed through the GlobalEnvironment Facility. Glob. Environ. Change 25. 97–108.

Bigot S.. Brou Y. T.. Bonnardot V.. Servat E.. 2002. Interannual stability of rainfall patterns in the Ivory Coast over the period 1950-1996. *IAHS Publ. No.* 274 : 507-514.

Bigot S.. Brou Y. T.. Oszwald J. & Diedhiou A.. 2005. Facteurs de la variabilité pluviométrique en Côte d'Ivoire et relations avec certaines modifications environnementales. *Sécheresse 6 (1)* : 5-13.

Bitty E. A.. Bi S. G.. Bene J. C. K.. Kouassi P. K.. McGraw W. S.. 2015. Cocoa farming and primate extirpation inside Cote d'Ivoire's protected areas. Tropical Conservation Science. 8(1). 95-113

Blasco F.. 1983. Mangroves du Sénégal et de Gambie. Rapport préparé à la demande de l'Organisation des Nations Unies. I.C.I.V. / CNRS. ER. 73. Université Paul Sabatier - Toulouse III. 86 p.

Brou Y. T.. 1997. Analyse et dynamique de la pluviométrie en milieu forestier ivoirien : recherche de corrélations entre les variables climatiques et les variables liées aux activités anthropiques. *Thèse de Doctorat 3ème cycle*. Abidjan. 210 p.

Brou Y. T.. 2010. Variabilité climatique. déforestation et dynamique agrodémographique en Côte d'Ivoire. *Sécheresse 21 (1)* : 1-6.

CARE International. 2009. Analyse de la Vulnérabilité et de la Capacité d'adaptation au Changement climatique. Manuel. 53p.

CDKN. ODI. 2014. The IPCC's Fifth Assessment Report: What's in it for Africa? Overseas Development Institute/Climate and Development Knowledge Network. London. UK (2014) 35 pp.

Clar C.. Prutsch A.. Steurer. R.. 2013. Barriers and guidelines in adaptation policy making: taking stock. analysing congruence and providing guidance. Nat. Resources Forum 37. 1–18.

Cochrane L.. Georgina Cundill G.. Ludi E.. New M.. Nicholls R.J.. Wester P.. Cantin B.. Murali K.S.. Leone M.. Kituyi E.. Landry M.E.. 2016. A reflection on collaborative adaptation research in Africa and Asia. Reg. Environ. Change.

Collins. J.M.. 2011. Temperature variability over Africa. *Journal of Climate* 24(14). 3649-3666. http://weathercenter.forest.usf.edu/docs/research/jcollins/Collins_Exch54.pdf

Das P.K. 2008. Responding to the Past. Preparing for the Future: Post Sidr Interventions in Education Bangladesh. DFID Bangladesh. Dhaka

Dorsouma Al – H.. Bouchard M-A.. 2006. Conflits armés et Environnement : Cadre. modalités. méthodes et rôle de l'Évaluation Environnementale. In. Développement durable et territoires [En ligne]. Dossier 8 : Méthodologies et pratiques territoriales de l'évaluation en matière de développement durable. mis en ligne le 28 février 2007. Consulté le 06 juin 2010. URL http://developpementdurable.revues.org/index3365.html

Engelbrecht. F.. Adegoke. J.. Bopape. M.-J.. Naidoo. M.. Garland. R.. Thatcher. M.. McGregor. J.. Katzfey. J.. Werner. M. et Ichoku. C.. 2015. « Projections of rapidly rising surface temperatures over Africa under low mitigation ». Environmental Research Letters 10(8). 085004. doi:10.1088/1748-9326/10/8/085004

Egnankou W.M. 1985. Etude des mangroves de Côte d'Ivoire : aspect écologique et recherches sur les possibilités de leur aménagement. Thèse de Doctorat de 3ème Cycle Ecologie. Université Paul – Sabatier TOULOUSE III. N° 3196. 176 p.

Egnankou. W. M. (1991). Carte des mangroves de FRESCO (Côte d'Ivoire). Unpublished.

Egnankou. W.M.. 1997– La *fermeture de la passe de Fresco et ses conséquences sur la productivité de la lagune N'GNI :* In Mangrove Ecosystem in Latin America and Africa – UNESCO. ISME and US Forest Service (Dpt of Agricult.) pp 271 – 283.

Egnankou W. M.. Sankaré Y.. 2004. Fiche descriptive sur les zones humides Ramsar (FDR). Fresco (Cote d'Ivoire).» Site web Ramsar 5p.

Egnankou W.M. 1989. Importance de l'Ecosystème mangrove dans la productivité des lagunes ivoiriennes. Communication présentée au Symposium international sur le Rôle de la Biologie dans la résolution de la crise alimentaire en Afrique organisé par le Réseau Africain de Biosciences.

Egnankou W.M. 1989. Mangroves et autres ressources des Zones Humides Côtières comprises entre Sassandra et Grand – Lahou. Rapport d'étude préparé à la demande de la Banque Africaine de Développement. 46 p.

Egnankou W. M.. 2018. Etude des Forêts et écosystèmes de mangroves dans le cadre de l'analyse de la vulnérabilité au changement climatique du paysage lagunaire de Fresco. 38p.

Ehuitché B. T.. 2015. An analysis of dynamics of deforestation and agricultural productivity in Côte d'Ivoire. International Research Journal of Agricultural Science and Soil Science. 5(4). 103-111.

Fadika V.. 2018. Etude des ressources en eau dans le cadre de l'analyse de la vulnérabilité au changement climatique du paysage lagunaire de Fresco. 52p.

Fadika V. (2012). Variabilité hydroclimatique et modélisation hydrologique de quelques bassins versants côtiers du Sud-Ouest de la Côte d'Ivoire. *Thèse Unique de Doctorat.* Université Abobo-Adjamé. Côte d'Ivoire : 199 p.

Friis-Hansen. E.. Bashaasha. B.. Aben. C.. 2013. Decentralization and Implementation of Climate Change Policy in Uganda. DIIS Working Paper 27. (https://www.diis.dk/ files/media/publications/import/extra/wp2013-17_ccri_uganda_efh_web.pdf. [6 January 2014]).

Funk C.. Michaelsen J.. Marshall M.T.. 2012. Mapping Recent Decadal Climate Variations in Precipitation and Temperature across Eastern Africa. In *Remote Sensing of Drought : Innovative Monitoring Approaches*. Wardlow. B.D.. Anderson. M.C. et Verdin. J.P. (eds.). CRC Press. chapitre 14

ftp://ftp.chg.ucsb.edu/pub/org/chg/products/FEWSNET_Trend_Analysis/final_bw_mapping_decadal_climate_variations.pdf

Gilmore S.. Saleem A.. Dewan A. 2015. Effectiveness of DOS (Dark-Object Subtraction) method and water index techniques to map wetlands in a rapidly urbanising megacity with Landsat 8 data. In Research@ Locate'15 (pp. 100-108). http: http://SunSITE. Informatik. RWTH-Aachen. DE/Publications/CEUR-WS/..

Goula Bi T. A.. Savané I.. Konan B.. Fadika V. et Kouadio G. B. (2006). Impact de la variabilité climatique sur les ressources hydriques des bassins de N'Zo et N'Zi en Côte d'Ivoire (Afrique tropicale humide). *VertigO - La revue en sciences de l'environnement* 7 *(1)* : 12 p.

Grab S.. Craparo. A.. 2011. Advance of apple and pear tree full bloom dates in response to climate change in the southwestern Cape. South Africa : 1973-2009. *Agricultural and Forest Meteorology* 151(3). 406-413

Hallegatte. S.. Lecocq. F.. De Perthuis. C.. 2011. Designing Climate Change Adaptation Policies. An Economic Framework. Policy Research Working Paper 5568.

Hepworth. N.D.. 2010. Climate Change Vulnerability and Adaptation Preparedness in Uganda. Heinrich Böll Foundation. Nairobi. Kenya (9 August 2013). http://www.ke.boell.org.

Hoffman M.T.. Cramer M.D.. Gillson L..Wallace M.. 2011. Pan evaporation and wind run decline in the Cape Floristic Region of South Africa (1974–2005) : implications for vegetation responses to climate. change. *Climatic Change* 109(3-4). 437-452 http://link.springer.com/content/pdf/10.1007/s10584-011-0030-z.pdf

Houghton J. Y.. Ding D.. Griggs. M. Noguer. van der Linden P.. Dai X.. K. Maskell. C. Johnson (eds.). Climate Change 2001: The Scientific Basis. Published for the Intergovernmental Panel on Climate Change. Cambridge University Press. Cambridge. United Kingdom. and New York. NY. USA. 881 pp.

Hubert P.. Bader J.-C. & Bendjoudi H.. 2005. Un siècle de débits annuels du fleuve Sénégal. *Impacts climatiques et anthropiques sur la variabilité des ressources en eau. Séminaire HSM. Montpellier. 22-24 novembre 2005* : 13 p.

Hughes R.H.. Hughes J.S. 1992. Répertoire des zones humides d'Afrique. UICN. Gland. Suisse et Cambridge. Royaume Uni/PNUE. Nairobi. Kenya/CMSC. Cambridge. Royaume-Uni xx + 808pp.

Hunter L. M.. Twine W.. Patterson L. 2007. Locusts are our beef: Adult mortality and household dietary use of local environmental resources in rural South Africa. *Scandanvian Journal of Health*. 35: 165-174

Hutchings P.. Saenger P.. 1987. Ecology of mangroves. Queensland (Australia): University of Queensland Press.

IPCC. 2014a. *Climate Change 2014: Impacts. Adaptation. and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Field. C.B.. V.R. Barros. D.J. Dokken. K.J. Mach. M.D. Mastrandrea. T.E. Bilir. M. Chatterjee. K.L. Ebi. Y.O. Estrada. R.C. Genova. B. Girma. E.S. Kissel. A.N. Levy. S. MacCracken. P.R. Mastrandrea. and L.L. White (eds.)]. Cambridge University Press. Cambridge. United Kingdom and New York. NY. USA. 1132 pp.

IPCC. 2014b. *Climate Change 2014: Impacts. Adaptation. and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Barros. V.R.. C.B. Field. D.J. Dokken. M.D. Mastrandrea. K.J. Mach. T.E. Bilir. M. Chatterjee. K.L. Ebi. Y.O. Estrada. R.C. Genova. B. Girma. E.S. Kissel. A.N. Levy. S. MacCracken. P.R. Mastrandrea. and L.L. White (eds.)]. Cambridge University Press. Cambridge. United Kingdom and New York. NY. USA. pp. 688.

IPCC. 2014c. Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Edenhofer. O.. R. Pichs-Madruga. Y. Sokona. E. Farahani. S. Kadner. K. Seyboth. A. Adler. I. Baum. S. Brunner. P. Eickemeier. B. Kriemann. J. Savolainen. S. Schlömer. C. von Stechow. T. Zwickel and J.C. Minx (eds.)]. Cambridge University Press. Cambridge. United Kingdom and New York. NY. USA.

IPCC. 2014d. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I. II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* [Core Writing Team. R.K. Pachauri and L.A. Meyer (eds.)]. IPCC. Geneva. Switzerland. 151 pp.

Issola Y.. Kouassi A. M.. Dongui B. K. et Biémi J.. 2008. Caractéristiques physico-chimiques d'une lagune côtière tropicale : lagune de Fresco (Côte d'Ivoire). *Afrique Science 04 (3)* : 368 – 393.. Disponible en ligne : http://www.afriquescience.info/docannexe.php?id=1357 (Page consultée le 01/02/2018).

Khajuria A.. Ravindranath N.H.. 2012. Climate Change Vulnerability Assessment: Approaches DPSIR Framework and Vulnerability Index. Journal Earth Sci Climat Change 2012. 3:1. http://dx.doi.org/10.4172/2157-7617.1000109

Kouadio Y.. Ochou D. A. et Servain J. (2002**)**. Atlantic influence on the rainfall variability in Côte d'Ivoire. *Geophys Res Lett 30* : 8005-8012.

Kouakou Y. E.. Kone B.. Cisse G.. Dje K. B.. N'go Y. A.. Konare A.. Savane I.. 2013. Environmental vulnerability index: application to the white Bandama bassin in the northern Côte d'Ivoire. International journal of conservation science Volume 4. Issue 3. July-September 2013: 357-369.

Kouakou K. E.. 2011. Impacts de la variabilité climatique et du changement climatique sur les ressources en eau en Afrique de l'Ouest : Cas du bassin versant de la Comoé. *Thèse Unique de Doctorat.* Université Abobo-Adjamé. Côte d'Ivoire : 186 p.

Lu. D.. Weng Q.. 2007. A Survey of Image Classification Methods and Techniques for Improving Classification Performance. *International Journal of Remote Sensing* 28 (5): 823–70. doi:10.1080/01431160600746456.

Lubès-Niel H.. Masson J. M.. Paturel J. E.. Servat E.. 1998. Variabilité climatique et statistique. Etude par simulation de la puissance et de la robustesse de quelques tests utilisés pour vérifier l'homogénéité de chroniques. *Revue des Sciences de l'Eau 3* : 383-408.

Madzwamuse. M.. 2010. Climate Governance in Africa: Adaptation Strategies and Institutions. http://www.za.boell.org. [6 January 2014].

Mahé G.. Paturel J.E.. 2009. 1896-2006 Sahelian rainfall variability and runoff increase of Sahelian rivers. *CR Geosciences; 341*: 538-46.

Mahé G.. Diello P.. Paturel J.M.. Barbier B.. Karambiri H.. Dezetter A.. Dieulin C.. Rouché N.. 2010. Baisse des pluies et augmentation des écoulements au Sahel : impact climatique et anthropique sur les écoulements du Nakambe au Burkina Faso. *Sécheresse 21 (1e)*: 1-6.

MINSEDD. 2017. Rapport de la troisième communication nationale de la Côte d'Ivoire dans le cadre de la convention cadre des nations unies sur les changements climatiques. *République de Côte d'Ivoire* : 132 p

Moss R.. Babiker M.. Brinkman S.. Calvo E.. Carter T.. Edmonds J.. Elgizouli I.. Emori S.. Erda L.. Hibbard K.. Jones R.. Kainuma M.. Kelleher J.. Lamarque J-F. Manning M.. Matthews B.. Meehl J.. Meyer L.. Mitchell J.. Nakicenovic N.. O'Neill B.. Pichs R.. Riahi K.. Rose S.. Runci P.. Stouffer R.. van Vuuren D.. Weyant J.. Wilbanks T.. van Ypersele J-P.. Zurek M.. 2008. *Élaboration de nouveaux scénarios destinés à analyser les émissions. les changements climatiques. les incidences et les stratégies de parade*. Résumé technique. Groupe d'experts intergouvernemental sur l'évolution du climat. Genève. 26 p.

Mouelhi S.. Michel C.. Perrin C. & Andréassian V.. 2006. Linking stream flow to rainfall at the annual time step : the Manabe bucket model revisited. *Journal of Hydrology 328* : 283-296.

NASAC. 2015. Climate Change Adaptation and Resilience in Africa. *Recommendations to Policymakers*. 42p.

N'guessan Y. A.. Adopo K. L.. Amani E. M.. Konan K. B.. Touré M.. Monde S..Aka K.. 2013. Etude bathymétrique. sédimentologique et environnement de dépôt des sables superficiels de la lagune de Fresco (Zone Ouest du littoral ivoirien). *Journal of Asian Research 3 (3)* : 308-320. Disponible en ligne : http://www.aessweb.com/pdf-files/jasr-3(3)-308-320.pdf (Page consultée le 26/04/2018).

Nguessan A. B.. Djè. K. B.. 2012. Changements Climatiques. agriculture et sécurité alimentaire en Afrique subsaharienne : le Cas de la Côte d'ivoire. Revue de Géographie Tropicale et d'Environnement. n°2. 2012.

Niang I.. Ruppel O. C.. Abdrabo M. A.. Essel A.. Lennard C.. Padgham J.. Urquhart P.. 2014. « Africa ». In *Climate Change 2014 : Impacts. Adaptation. and Vulnerability. Part B : Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Barros. V.R.. C.B. Field. D.J. Dokken. M.D. Mastrandrea. K.J. Mach. T.E. Bilir. M.*

Chatterjee. K.L. Ebi. Y.O. Estrada. R.C. Genova. B. Girma. E.S. Kissel. A.N. Levy. S. MacCracken. P.R. Mastrandrea. et L.L.White (eds.)]. . Barros. V.R.. C.B. Field. D.J. Dokken. M.D. Mastrandrea. K.J. Mach. T.E. Bilir. M. Chatterjee. K.L. Ebi. Y.O. Estrada. R.C. Genova. B. Girma. E.S. Kissel. A.N. Levy. S. MacCracken. P.R. Mastrandrea. et L.L. White (ed.). Groupe intergouvernemental d'experts sur l'évolution du climat (GIEC. Cambridge University Press. Cambridge. Royaume Uni et New York. NY. États-Unis. p. 1199-1265.

Nicholson S. E.. Nash D. J.. Chase B. M.. Grab S. W.. Shanahan T. M.. Verschuren D.. Asrat A.. Lézine A.-M.. Umer M.. 2013. Temperature variability over Africa during the last 2000 years. *The Holocene* http://hol.sagepub.com/content/early/2013/04/23/0959683613483618.full.pdf+html

Nicole M.. Egnankou Wadja M.. Schmidt M.. 1987. Les zones humides côtières de Côte d'Ivoire. IUCN. Gland. Suisse. (ORSTOM-CI Nature/Univ.CI-UICN) 73 pp.

Orindi. V.A.. 2013. Evaluation of the Status of NAPA/NAP in Ethiopia. Tanzania. Uganda and Kenya. Climate Change Agriculture and Food Security (CCAFS) (6 January 2014). https://ccafs.cgiar.org/.

Otieno. P.S.. Ogutu. C.A.. Mburu. J.. Nyikal. R.A.. 2017. Effect of Global-GAP policy on smallholder French beans farmers' climate change adaptation strategies in Kenya. Afr. J. Agric. Res.

Paturel J. E.. Servat E.. Kouamé B.. Lubès-Niel H.. Masson J.M.. Boyer J. F.. Travaglio M.. Marieu B. 1997. Variabilité pluviométrique en Afrique humide le long du Golfe de Guinée. Approche régionale intégrée. *PHI-V No. 16. Unesco. Paris* : 1-31.

PECCN (Poverty. Environment and Climate Change Network). 2011. Understanding Vulnerability to Climate Change. Denmark.

PNUE. 2015.Côte d'Ivoire. Évaluation environnementale post-conflit. 154p.

Pramova. E.. Di Gregorio. M.. Locatelli. B.. 2015. Integrating Adaptation and Mitigation in Climate Change and Land-use Policies in Peru. Working Paper 184. CIFOR. Bogor. Indonesia (20 September 2015). http://www.cifor.org/publications/pdf_files/WPapers/WP184Pramova.pdf.

Rwakakamba. T.S.. 2009. How effective are Uganda's environmental policies? Mt. Res. Dev. 29 (2). 121–127.

Ringard J.. Dieppois B.. Rome S.. Dje K. B.. Konaté D.. Katiellou G. L.. Lazoumar R.. Bouzou-Moussa I.. Konaré A.. Diawara A.. Ochou A.D.. Assamoi P.. Camara M.. Diongue A.. Descroix L.. Diédhiou A.. 2016. Evolution des pics de températures en Afrique de l'ouest : étude comparative entre Abidjan et Niamey.

Saenger P.. Moverly J.. 1985. Vegetative phenology of mangroves along the Queensland coastline. Proc. Ecol. Soc. Aust. 13:257-65.

Sankaré Y. Aka K. S.. 2016. Risques. menaces. opportunités et vulnérabilités socio-économiques lés au changement climatique du paysage de Fresco. Côte d'Ivoire (Afrique de l'Ouest). 56p.

Sankaré Y. Bouberi D.. Tidou A. Egnankou W. M.. 2001. Les zones humides de Côte d'Ivoire. Rapp. Centre African for Wetlands (CAW). Accra-Ghana. 89p.

Servat E.. Paturel J. E.. Lubès-Niel H.. Kouamé B.. Masson J.M.. Travaglio M.. Marieu B. 1999. De différents aspects de la variabilité de la pluviométrie en Afrique de l'Ouest et centrale non sahélienne. *Revue des sciences de l'eau 12 (2)* : 363-387.

SODEXAM. 2014. Etat du climat de l'année 2013 en Côte d'Ivoire. Département de la Climatologie et de l'Agrométéorolgie. Direction de la Météorologie Nationale. Février 2014.

Soro S. Ouattara D. Egnankou W. M.. N'guessan K. E.. Traore D. 2014. Usages traditionnels de quelques espèces végétales de la foret marécageuse classée de Port Gauthier. en zone côtière au Sud-ouest de la Côte d'Ivoire. *European scientific journal Research*

Thondhlana. G.. Shackletona. S.. Blignaut. J.. 2015. Local institutionsactors. and natural resource governance in Kgalagadi Transfrontier Park and surrounds. South Africa. Land Use Policy 47 (2015). 121–129.

UNECA. 2014. *Loss and damage in Africa.* 60p.

UNEP 2016. GEO-6 Regional Assessment for Africa. United Nations Environment Program. Nairobi. Kenya.. 206p.

UNEP. 2013. *Africa Environment Outlook 3 : Our Environment. Our Health.* Africa Environment Outlook. 242p.

UNEP. 2007. Global Environment Outlook 4. *Environment for developpement*. 572p

Urwin. K.. Jordan. A.. 2008. Does public policy support or undermine climate change adaptation? Exploring policy interplay across different scales of governance. Global Environ. Change 18. 180–191.

Vliet Nathalie van. Ole Mertz. Andreas Heinimann. Tobias Langanke. Unai Pascual. Birgit Schmook. Cristina Adams. 2012. Trends. Drivers and Impacts of Changes in Swidden Cultivation in Tropical Forest-Agriculture Frontiers: A Global Assessment. *Global Environmental Change* 22 (2). Elsevier Ltd: 418–29. doi:10.1016/j.gloenvcha.2011.10.009.

Weis S. W. M.. Agostini V. N.. Roth L. M.. Gilmer B.. Steven R.. Knowles J. E.. Blyther R.. 2016. Assessing vulnerability: an integrated approach for mapping adaptive capacity. sensitivity. and exposure. Climatic Change (2016) 136:615–629 DOI 10.1007/s10584-016-1642-0

Wondrade N.. Øystein B. D.. Havard T.. 2014. GIS Based Mapping of Land Cover Changes Utilizing Multi-Temporal Remotely Sensed Image Data in Lake Hawassa Watershed. Ethiopia. *Environmental Monitoring and Assessment* 186 (3): 1765–80. doi:10.1007/s10661-013-3491-x.

Yao A. B. 2015. Evaluation des potentialités en eau du bassin versant de la Lobo en vue d'une gestion rationnelle (Centre Ouest de la Côte d'Ivoire). *Thèse Unique de Doctorat.* Université Abobo-Adjamé. Côte d'Ivoire : 225 p.

Yao A. N'G.. Kouassi L A.. Etche M.. Amani K.B. K.. Mamadou T. S.. Monde K. A.. 2013 Etude bathymètrique. sedimentologique et environnement de depots des sables superficiels de la lagune de fresco (zone ouest du littoral ivoirien) journal of asian scientific research. 2013. 3(3):308-320

Young Nicholas E.. Ryan S. Anderson. Stephen M. Chignell. Anthony G. Vorster. Rick Lawrence. and Paul H. Evangelista. 2017. A Survival Guide to Landsat Preprocessing. *Ecology* 98 (4): 920–32. doi:10.1002/ecy.1730.

Zougmoré. R.. Partey. S.. Ouédraogo. M.. Omitoyin. B.. Thomas. T.. Ayantunde. A.. Ericksen. P.. Said. M.. Jalloh. A.. 2016. Toward climate-smart agriculture in West Africa: a review of climate change impacts. adaptation strategies and policy

LIST OF FIGURES

LIST OF TABLES

LIST OF PHOTO GALLERIES

U.S. Agency for International Development
1300 Pennsylvania Avenue, NW
Washington, DC 20523
Tel: (202) 712-0000
Fax: (202) 216-3524
www.usaid.gov