CLIMATE CHANGE AND ITS IMPACT ON OCCURRENCE OF *SARGASSUM NATANS* AND *SARGASSUM FLUITANS* ON COASTLINE OF LAGOS AND ITS ENVIRON

BY

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MTech/SPS/2015/6066

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THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF MASTER OF TECHNOLOGY (MTECH) IN CLIMATE CHANGE AND ADAPTED LAND USE

MARCH, 2018

DECLARATION

I, hereby declare that this thesis, titled **"Climate Change and its Impact on Occurrence of S*argassum natans* and S*argassum fluitans* on Coastline of Lagos and its Environ"**, is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published or unpublished) has been duly acknowledged.

ADET, Lucette

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MTech/SPS/2015/6066

SIGNATURE / DATE

FEDERAL UNIVERSITY OF TECHNOLOGY,

MINNA, NIGERIA.

CERTIFICATION

The thesis titled: **''Climate Change and its Impact on Occurrence of S*argassum natans* and S*argassum fluitans* on Coastline of Lagos and its Environ''** by ADET, Lucette (MTech/SPS/2015/6066) meets the regulations governing the award of the degree of Master of Technology of the Federal University of Technology (MTech), Minna and it is approved for its contribution to scientific knowledge and literary presentation.

Prof .G.N. Nsofor ……………………..

Supervisor Signature & Date

Prof. A. A. Okhimamhe ....………………..

Director, WASCAL CC&ALU Signature & Date

Prof. M. G. M. Kolo ……………………..

Dean, Postgraduate School Signature & Date

DEDICATION

This thesis is dedicated to the Almighty God as a thanksgiving action for his immense love. Secondly, this work is dedicated to my parents, Mr and Mme Grodon Adet, who guided my first steps. May you find here, father and mother my pride, one of the fruits of your sacrifices in my life. And also my confident and love to have trusted in me and supported me, thank you.

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ABSTRACT

Climate change is an important emerging threat to every kind of life on earth, especially in the areas where populations are economically poor. West Africa is part of them and vulnerable to the effects of climate change. Among those effects are the shifts of algae species from their native place to new areas more suitable. As a result of warming oceans, aquatic species shifted their distribution. This is the case for two algae species identified as *Sargassum natans* and *Sargassum fluitans* which shifted from the Brazilian coast to West African coast. The occurrence of these algae along the Nigerian coast was the subject of this study. The species affect mostly food security and coastal population economy. The aim of this study is to examine the impacts of climate change on spatial distribution of *Sargassum natans* and *Sargassum fluitans* along the coast of Nigeria through the analysing of the relationship between climate change variables and their spatial distribution; analysing remote sensing images to map *Sargassum* distribution from 2011-2016; evaluation of the perception of coastal residents on the presence of S*argassum* on the banks and their notion of climate change; and evaluation of the past trend of the major variables that drive *Sargassum* phenomena along the Nigerian shores. To achieve these objectives, a combined quantitative and qualitative approach was performed to study coastal communities perceptions among household heads in Lagos State where a total of 206 household heads were interviewed. The outputs were analysed using R software. The monthly images from Modis Aqua GIOVANNI on normalized Fluorescence Line Height (nFLH) between 2011 to 2016 were displayed in Seadas software to highlight spatial algae blooms along the Nigerian coast. Through a Principal Component Analysis (PCA) method performed in R software on six (6) oceanic parameters listed as sea surface salinity, precipitation, sea surface temperature, wind and ocean current component from 2011 to 2016. The relationship between these parameters and *Sargassum* species distribution were analysed also, the trends of these oceanic parameters were analysed. The results show that the knowledge about climate change and the reason of the occurrence of *Sargassum* is limited (69.9%) due to low level of education and limitation of information access. Also, the climate change and the presence of *Sargassum* species have several consequences on the respondents' livelihood and activities (77.7%). Moreover, the analysis of Modis Aqua image reveals the past spatio-temporal patterns of *Sargassum* species along the Nigerian coast. The species fluorescence does not fit with the monthly range trends reported by previous studies. Indeed, that would correspond to an undetected *Sargassum* species patterns or another algae specie with almost the same fluorescence characteristics. Furthermore, The principal variables involved in their motions are the wind patterns associated with the horizontal current velocity. The parameters such as v-velocity, salinity, precipitation, sea surface temperature, play important but indirect roles in the shift and the distribution of *Sargassum* species. Finally, there is temporal trend in the oceanic parameters which evolve together and lead to *Sargassum* species new distribution. *Sargassum* events in Nigerian coast could be mostly explained by and how long the oceanic parameters have reacted to the climatic changes which affect the species. As recommendations, coastal population must be educated about climate change, winds and currents motions must be monitored to predict *Sargassum* events, fishermen must be assisted in their activities.

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LIST OF ABBREVIATIONS

AAS: Atomic Absorption Spectroscopy

CHLa: Chlorophyll a

CORDEX: Coordinated Downscaling Experiment

ENSO: El Nino-Southern Oscillation

ENVISAT: Environmental Satellite

EPA: Environment Protection Agency

EVI: Enhanced Vegetation Index

FAI: Floating Algae Index

Ghg: Greenhouse Gases

GPA: Global Programme of Action for the Protection of the Marine Environment from Land-based Activities

GPS: Global Positioning System

GtC: Gigaton carbon

HABs: Harmful Algae Blooms

H_2S: Sulfide of hydroxide

HYCOM: Hybrid Coordinated Ocean Model

IOCCG: International Ocean Color Coordinating Group

IPCC: International Panel of Climate Change

ITCZ: Intertropical convergence Zone

JASP: Java based statistical processor

MCI: Maximum Chlorophyll Index

MERIS: Medium Resolution Imaging Spectrometer

MRE: Modis Red Edge

MODIS: Moderate Resolution Imaging Spectroradiometer

NASA GSFC: National Aeronautic and Space Agency - Goddard Space Flight Center

Rrc:	Rayleigh reflectance
NERR:	North Equatorial Recirculation Region
NDVI:	Normalized Different Vegetation Index
NGO:	National Government Organisation
NIR:	Near Infrared
NOAA:	National Oceanic and Atmospheric Administration
OCR:	Ocean Colour Radiance
PCA:	Principal Component Analysis
PSU:	Practical Salinity Unit
ROMS:	Regional Ocean Model System
SST:	Sea Surface Temperature
SWIR:	Short Waves Infrared radiation
UNEA:	United Nation Environmental Assembly
UNEP:	United Nation Environmental Programme
UNFCC:	United Nations Framework Convention on Climate Change
USAID:	United States Agency for International Development
WABiCC:	West Africa Biodiversity and Climate Change
WOD:	World Ocean Database

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Climate change is considered a global phenomenon that is manifested through an increase in the global average temperature of 0.18°C to 0.74°C during the 20th century. Statistical evidences from the Fourth Assessment Report of Intergovernmental Panel on Climate Change (IPCC) have shown that climate has been changing. This change is bound to have cross cutting effects on the environment, including the oceans and its inhabitants. When the average long-term weather patterns of the environment are altered over a long period, several changes occur such as rise of sea level, rise of sea surface temperature, unbalance of sea salinity; this current climatic variation drives the shifts in wind patterns, the average temperature, and the amount of precipitation. Also, future prediction has shown an increase of global temperature lead by Greenhouse gases (Ghg) increasing in the atmosphere (IPCC, 2007).

Climate change has diverse consequences on marine ecosystem. Thus, changes in ocean temperature and chemistry can affect the productivity of species and the way they behave. That directly, led to shifts in the size structure, spatial and seasonal abundance of aquatic species. Climate change as well as modified ocean circulation can change species distribution and the supply of nutrient which ensure a connectivity quite great over marine species habitats. Furthermore, physiological responses of organisms to climate change would represent by shifts in abundance, timing of annually recurring events, the distribution and dispersion of marine species (Doney *et al*., 2012).

A study by Sorte *et al*. (2010) showed that more than 70% shift in marine range is as a result of climate change and increasing global temperatures. Widespread biogeographical range shifts are associated with changing climatic conditions in marine environments. According to Gower and King (2011) there have been new coastal dispersion of algae species, identified as the *Sargassum* species. For example, beaching was unknown in West Africa before 2011 and could be a response to the climate change effects. Thus, United Nations Environmental Programme UNEP (2016) has pointed out that *Sargassum* cycles are closely linked to a seasonal change of the sea surface temperature, which drives *Sargassum* species patterns in the Eastern Caribbean and Northwest African coastlines.

Similarly, Satellite imagery has also shown this assertion to be true as this technology has aided the visualization of these species on sea surface. The images have shown that the *Sargassum* seaweed blossoms in the Sargasso Sea and in the northern part of Brazil, extending two million square miles in the warm waters of the North Atlantic Ocean. During the spring of 2011, some scientists observed that there was a massive migration of pelagic *Sargassum* from the Caribbean islands, northern Brazilian coast to the coast of Sierra Leone and the Gulf of Guinea, with the images showing an unusual spreading in the tropical Atlantic area. Although, the distribution of species can be attributed to a natural or to the unknown drivers, changes in ocean patterns due to global warming have also been implicated in this trend.

These changes in the movement and population of *Sargassum natans* and *Sargassum fluitans* require some interrogations. Therefore, the task of this work is to find out the effects of global warming, (climate change) on *Sargassum natans* and *Sargassum fluitans* distribution in coastal West African waters particularly along Nigeria's coastal landscape.

1.2 Statement of the Problem

Various climate change forcings' at the coasts constitute a complex array of management challenges and adaptation requirements. Warming oceans have resulted in many aquatic organisms shifting their distribution towards favourable environment. Climate-related distribution shifts contribute to observed modifications in composition and biodiversity of many systems and organisms communities (Doney *et al*., 2012). Climate change is a reality and everybody agrees with this fact; some evidences exist to prove that climate change provokes a great threat for development especially for the developing countries. Climate change and shifts of bloom algae are likely to impact coastal areas because of the continual increasing of sea temperature and of shifts events frequency.

Since 2011, the massive deposits of *Sargassum* algae along the coast of West African have been remarked. This coastal area provides important services to society such as production of food, employment, livelihood and recreation for the communities. The *Sargassum* presence on shores affects residents and causes several socio-economic issues, for example, reduction of coastal communities incomes, food security and food availability. Coasts in developing countries are particularly vulnerable to climate change impact due to the direct exposure to extreme weather events. Excessive algae masses can cover tourist beaches, sand bays, and can cause numerous environmental problems. Also, it is difficult to predict their coming and in what amount so as to enable for a better management of the threats posed by these species.

If these trends continue uncontrolled, food security (fisheries, shrimps, crabs) may not be attained for the population. *Sargassum* species events in West Africa and other areas in the world have received media attention, some actions by regional governmental agencies and environmental groups checking to get a clearer understanding of the problem. It seems that questions that this problem have not been considered as important enough, thus, as echoed by Hu *et al*. (2016) the driving factors of *Sargassum* beaching events remain unknown. Few studies in Africa have addressed the function of weather in the upheaval of *Sargassum*'s migration. Addressing these uncertainties by effective monitoring and forecasting systems will be considered as an advancement in the problem solving.

1.3 Aim and Objectives

The aim of this study is to examine the impacts of climate change on spatial distribution of *Sargassum natans* and *Sargassum fluitans* along the coast of Nigeria.

The specific objectives are to:

(i) analyse the relationship between climate change variables and the distribution of algal species,

(ii) map the spread of *Sargassum* species distribution from 2011-2016 along the Nigerian coast,

(iii) evaluate the perception of coastal residents about climate change impact on the occurrence of S*argassum* species on Nigeria coastline,

(iv) examine the past trend of the major variables that drive *Sargassum* species phenomena along the Nigerian shores.

1.4 Research Questions

The following research questions were outlined from the above objectives:

(i) Is there a relationship between climate variability and *Sargassum* distribution?

(ii) What is the previous *Sargassum* distribution patterns from 2011-2016?

(iii) What is the perception of of coastal residents about climate change impact on the occurrence of S*argassum* species on Nigeria coastline?

(iv) What is the likely past trend of the climate parameters variability driving *Sargassum* phenomena along the Nigerian shores?

1.5 Justification for the Study

The Intergovernmental Panel on Climate Change (IPCC) evaluated the extent recent observations made about changes in natural biological systems to climate change. It has predicted that, based on the increase of greenhouse gases (Ghg) concentration mostly the carbon dioxide (CO_2) will increase over time, the global surface temperature also will continue to increase by 1.4 - 5.8°C by 2100. Moreover, the records of temperature across African continent have predicted a rising of temperature by 2 - 6°C over the next 100 years and the warming of Africa (Gemeda and Sima, 2015). Africa which is the lowest emitter continent of greenhouse gases (Ghg) is the most vulnerable continent affected by climate change (Beg *et al*., 2002). With lower institutional, technical and financial capacity to adapt; their tools to face this hazard is still primitive.

This study is in view to contribute to a better understanding of the algae species movement from their native zone to West Africa especially along Nigeria coast because the reasons for Pelagic *Sargassum* species distribution in biomass stay undetermined yet. This phenomenon is in progress and as at this time is uncontrollable. Research could offer insights and meanings that may illuminate this subject that worries the coastal residents and affects more and more the stability and the future of shores. Also, this work attempted to find out the major elements that drive those species to undertake new distribution patterns, and the role of climate change in the assessment of *Sargassum* apportionment. It tried to answer the question of what are the social and economic repercussions of this event on the population. Also, the result of this study could be useful in implementing adaptation strategies and measures. Indeed, less scientific works in West Africa has covered this topic, the knowledge about it is limited and the information searching is still a discovery. It is believed the research outputs may be applied to other coastal regions in the country in particular and largely to West Africa countries touched by the similar challenges.

1.6 Scope

Nigeria coastline, key territory where *Sargassum* events have occurred, constitutes the study area of this research. Imagery were collected within previous literatures that means GPS coordinates of *Sargassum* distribution along the West African coast to map ground-truth data over 2011-2016. Furthermore, this study focused on the determination of oceanic parameters affected by climate change which contribute to the *Sargassum* patterns along the Nigerian coast. These parameters such as sea surface temperature, sea surface salinity, nutrients, winds, ocean currents, precipitation, covering West African coast, precisely Nigeria coast from 2011 to 2016, because of the role climate change plays in the shift of *Sargassum* towards the coast.

1.7 Study Area

1.7.1 Location description

Sargassum natans and *Sargassum fluitans* have been found offshore/onshore on the West Africa coast Széchy *et al*. (2012) particularly in Nigeria (Oyesiku *et al.,* 2014). According to National Bureau of Statistics (2011) located between 3° and 14° East Longitude and 4° and 14° North Latitude, the Federal Republic of Nigeria is defined with an area of 923,769 square kilometers with 909,890 square kilometres of land area and 13,879 square kilometres of water area. The Nigerian coast measures 853km long, extends across seven Southern States listed as: Lagos, Ondo, Delta, Bayelsa, Rivers, Akwa Ibom and Cross Rivers bordering the Atlantic Ocean and lies between longitude 2° 45’ to 8°35’E and latitude 4°10’ to 6°20’ N (See Figure 1.1). For the third objective of this study, Lagos State, were considered.

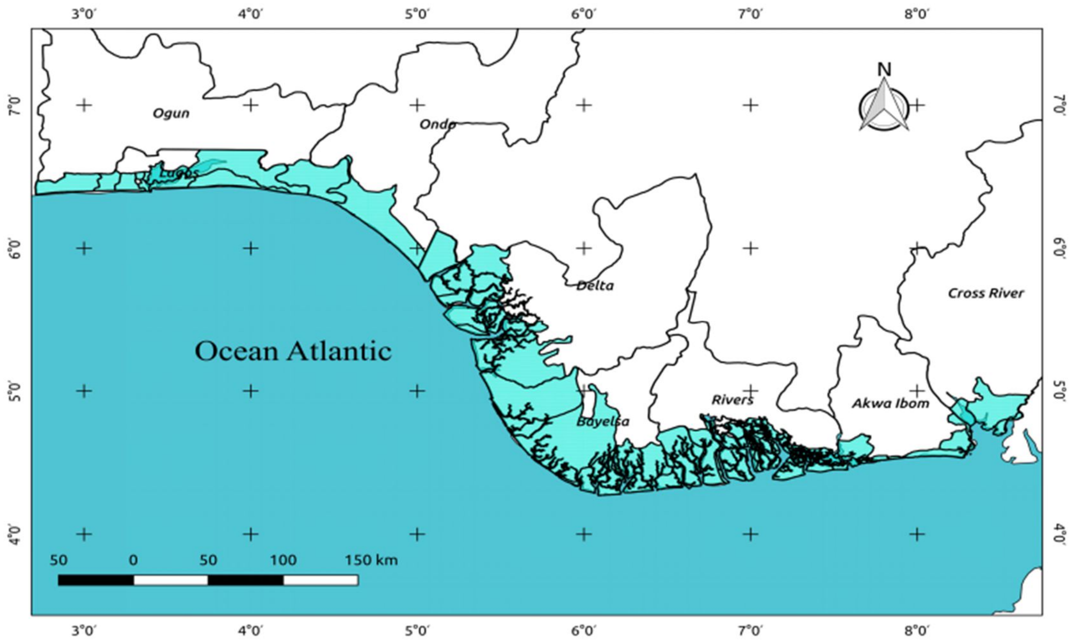


Figure 1 Coastal map of the study area

1.7.2 Climate

Along the coast and south-eastern areas of Nigeria, the rainy season usually starts in February or March as moist Atlantic air defined as the south-west monsoon that covers all the country. The rainy season starting is characterised by the presence of high and strong winds that scatter squalls whose quality is particularly noticeable in the north in dry years. The highest amount of total rainfall is located in the south-east, along the coastal area of Bonny and east of Calabar, with a mean annual rainfall of more than 4,000 millimeters. The rest of the south-east regions receives around 2,000 ~ 3,000 millimeters of rain per year. The lower total precipitation is noted in south-west area around 1,250 ~ 2,500 millimeters per year. Nigeria temperature is generally high with diurnal variations, more pronounced than seasonal variations. The dry season is characterized by highest temperatures, moderated rains in afternoon and high in the wet season. Average temperatures vary little from coastal to inland areas (National Bureau of Statistics, 2011). The southern coastline of Nigeria, with a sub-equatorial climate, is a low-land area (20-50 meters) submits to the south-west trade wind, with a tropical rainforest characterised by tall evergreen tree (Fatai, 2011).

1.7.3 Socio-economic activities

Nigerian coastal regions have several activities which participate in their development and to the reinforcement of the communities' economy. Among these activities, cultural activity is one of the paramount motivations in the choice of the tourist destinations all over the world. The specific cultural events provide important flows of population and constitute a vector of regional promotion. The coastal tourism constitutes the primary and secondary economic activities of the communities. Coastal tourism is based on the land and sea resources; the coast gives several tourist amenities (beaches, terrestrial and marine biodiversity), and contribute to diversify, socio-cultural and economic activities. It encourages other coastal activities like fishing, aquaculture, boats transport and so on (Fatai, 2011).

Fishing is one of the major occupations of the coastal communities with attracts traders and consumers from the nooks and crannies. It is often associated with collection of shrimps, crabs, and other palatable sea organisms. As a result of several socio-economic activities the coastal areas subsist and are developing (Olufayo *et al*., 2013).

CHAPTER TWO

2.0 LITERATURE REVIEW

In this chapter some concepts such as climate change, climate variability, and its impacts on sea species, perception of the coastal communities with respect to climate change, coastal area, ocean parameters, ocean colour and chlorophyll and the effects of *Sargassum natans*, *Sargassum fluitan*s presence on the coast were reviewed. These concepts are useful in the understanding of the study. In addition to this, some relevant literatures were also reviewed. They encompass the species characteristics (spatial, temporal, biological), the methods previously used to actualise them.

2.1 Conceptual Framework

2.1.1 Perception of the coastal communities

Climate change impacts are significant stressors to physical and environmental population, their ability and their socio-economic activities. The effects of the change in the climate are more felt and experienced by human. These influence human welfare, human wealth and activities. The change of current weather conditions of marine environment contributes to the shifts of species which impact the people who live near the coastline. The coastal environment in Africa is the attractive destination for tourism which contributes to national economies and coastal communities incomes. However, Lyimo *et al*. (2013) reported that most households perceive climate change indicators changes in rainfall, temperature, sea level rise, drought and wind. But wind as indicator of climate, received more responses by coastal fishing villages because, of its interference to their activities. Fishermen are more concerned about wind and its changes because of their occupation. For them, wind is very crucial and it is important to be able to predict tidal patterns. With regards to floods, there was high response in the area because of its frequent occurrence. According to the researcher, most of the respondents acknowledged occurrence of change in climatic conditions which have impact on their livelihood. They observed that sea level rise has been perceived as indicator of climate change by coastal communities because of the salinity which affects fresh water and the level of water.

According to Bennett *et al*. (2014) in their study coastal people are sensitive to the impact of climate change because they are reliant on the products from marine habitats. In addition, the houses and infrastructures are impacted by the increasing unpredictable weather patterns such as sea rising. Adaptive measures to reduce people vulnerability could be designed based on the stressors facing by the coastal residents at different levels of modifications. Climate change related stressors mentioned by the respondents included flooding, saltwater intrusion, sea level rise, coral bleaching, precipitation and storm events increasing, have direct effects on household assets, livelihood outcomes and population buildings.

2.1.2 Coastal area

The coastal environment is generally defined as 'any piece of land next to, bothering or adjourning the sea shore' (Akankali and Elenwo, 2015). According to them, the coastal area is low lying with approximately 3.0 m heights above sea level and in some cases get along with certain ecosystems such as fresh water swamp, mangrove swamp, lagoon mashes, tidal channels, beach ridges and sand bars. Also, it refers to the narrow linear corridor of shore line separating the continental shelf from the oceanic land mass whose extent (inwards, towards the continental shelf and outwards) varies immensely, in function of the context which defined it. Coastal areas are rich of mineral and biodiversity resources.

Climate change imposes additional stresses on the coasts. The sustainability of coastal population and their resources is threatened by the intensity of climatic extremes and the increasing of human development. Although the climate is warming at a global scale, the impact varies across coastal areas. Several effects such as rising sea level, Harmful Algae Blooms (HABs) development, sea temperature increasing, are already evident in beaches. In addition, the primary leading forces are changes in temperature, changing ocean circulation patterns, precipitation, waves, winds and currents, which together render the coasts sensitive to climate change impacts. A changing global climate associated with human activity imposes additional stresses on coastal regions. Thus, toxic algae blooms events have increasing with excess nitrogen and other chemicals present in the nearshore water (Burkett and Davidson, 2012).

2.1.3 Climate change vulnerability

Vulnerability to climate change has been defined as: 'The degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity' (IPCC, 2007); http://www.careclimatechange.org/tk/cba/en/cba_basics/key_concepts.html.

It implies that a system is vulnerable if it is exposed and sensitive to the effects of climate change and at the same time has only limited capacity to adapt and less vulnerable if it is less exposed, less sensitive or has a strong adaptive capacity, although, some species can adapt by shifting toward suitable areas. Thus, marine species sensitivity to climate is truly a good indicator of warming oceans over years (EPA, 2016) and affected many domains such as water, agriculture resources, food security, biodiversity, human health and coasts (UNFCCC, 2007).

2.1.4 Climate change and impact on sea species

Responses to climate change are quite strong and quick where species live at their upper temperature tolerance limits. As a result of global warming, shifts of marine species occur with an average of 19 km/year exceed the 0.6 km/year of terrestrial species. Furthermore, climate change contributes to the range shifts of marine species in accordance with their thermal tolerance limits (Jueterbock *et al*., 2013). Climate change is leading several plants species to modify their geographic distributions in tracking favourable climate conditions. Changes in species ranges associated with global warming have already been ascertained in a broad variety of species, associations, and ecosystems on all continents and in most oceans. The measure of shifts is based on range boundaries or the abundance changes which occur within species communities. Thus, the change of the range and the abundance of species shifts are made over time periods (Bellard *et al*., 2012). The migration of species induced by climate change is not a new phenomenon. During the late Quaternary, several species were displaced in response to climate change (Gill *et al*., 2009). Changing climate impact species and ecosystems directly in diverse ways. It influences principal stages of the annual life cycle of the species, such as, blooming, reproduction, migration of the species and ecosystem vulnerability.

For example, in addition to warming, there are sea level rises, saltwater intrusion which may force species to resettle or die (IPCC, 2014). The increase of precipitation which induces flooding washes away fertilizer and sewages directly into water bodies which become rich in nutrient, furthering harmful algal blooms. For instance, the 2012 flood which happened in the Niger Delta would have brought enough pollutants into the water bodies in the area, driving the emergence of harmful algal bloom. The disturbance in the climate affects the harmful algal bloom occurrence because their growth, toxicity, and geographic distributions are influenced by climate variability. Also, evidences indicated that climate warming can profit algal species by providing optimal conditions for their growth (Elenwo and Akankali, 2014).

2.1.5 Ocean parameters

The ocean covers more than 70% of the planet's surface and is so immensely deep that it contains over 90% of the inhabitable space for life on Earth. All parts of this space are filled with wide biodiversity (Herr and Galland, 2009). The ocean is a important source of nourishment, in particular for developing country population which depend mostly on fishing and aquaculture to support directly or indirectly around 540 millions of person (Akankali and Elenwo, 2015). Because it influences the distribution of heat in the atmosphere and the oceans, climate change would affect the oceanographic and climatic parameters over the sea and along the nation's coasts.

2.1.5.1 Ocean currents and upwelling

The current is defined as water in continuous motion. The primordial ocean currents are caused by the drag on sea surface due to wind stress. In polar zone, the temperature would be high which affect wind stress. Knowing that the winds are created by the unequal warming of the system earth's surface, any disturbance of wind pressure would lead to a weakening of the overall wind circulation associated with thermohaline (temperature (thermo) and salinity (haline)) circulation which furthers currents motions (NOAA, 2015). When climate changes impact these circulations patterns, different movements can contribute to the reduction of species abundance within estuaries and along the coast that will modify coastal ecosystems and fishery yields. Ocean currents influence the life in the ocean, because they lead to and manage the physical conditions furthering the development of all marine life.

Upwelling defined as being the vertical motion of subsurface water towards the ocean surface precipitates the nutrient circulation and constitute an element of the global thermohaline circulation. This physical process impacts marine life in the areas where it occurs because of the nutrient enrichment of the ocean surface which increases primary productivity with a mean estimated at 300 g C $m^{-2}y^{-1}$. This value proves how much upwelling systems exerts on marine life in the area where it prevails. The equatorial upwelling systems is characterized by creating a surface of divergence where surface water removed from the zone have to be filled by the water mass from shallow layers. These surface divergences are built by the wind and the equatorial currents near the equator lines within Atlantic ocean and extended over a large region. With low nutrients amount, the equatorial upwelling intensity is less in this zone compared to the eastern boundary upwelling systems. Thus, its influence on the marine productivity is weak.

As reported, the density is defined as the difference between the surface layer and shallow layer of the waters controlled by vertical movements and water exchange between them. Therefore, in the high latitude regions over surface ocean, water can increase its density and sink towards a deeper level. It is the example in the North Atlantic, the areas where seawater salinity is high due to the fact that evaporation exceeds rainfall in the Mediterranean and Sargasso Seas. The development and keeping of upwelling processes depend on the winds' strength and direction, and the presence of nutrient-rich water under the pycnocline (layer near ocean surface where the density gradient increase rapidly) (Merino and Monreal-Gómez, 2009).

Although, the upwelling and the coastal currents along the West African coast are subject to important seasonal fluctuations in response to the local winds' variability, hence, upwelling is considered as intense off the south-western Africa region, and associated to the surface temperatures which are minimum when the local coastline winds are most intense. The northern coast of the Gulf of Guinea has seasonal upwelling characterized by low temperatures in the northern summer; there, the thermocline depends on winds everywhere in the equatorial Atlantic. Moreover, eastern tropical Atlantic warming induces the weak winds and also changes in atmospheric conditions (Philander, 2001; Hormann *et al*., 2012).

As advocated by Piontkovski *et al*. (2003) the currents along the West African coast coupled with the upwelling play a great role in the nutrient-enrichment of the waters. Thus, the frequency and intensity of upwelling events lead to primary and secondary development and proliferation of the epipelagic ecosystem. *Sargassum* species bloom occurred in the North Equatorial Recirculation Region (NERR) of the North Atlantic between the North Equatorial Counter Current and the equator. The NERR located between Brazil and Africa favour the growth of pelagic *Sargassum* species through the availability of nutrient and iron. Historical maxima and minima during 2009- 2011 of climatic indices favoured recirculation and development of *Sargassum* species (Franks *et al*., 2014)

2.1.5.2 Guinea current

Always north of the equator, the southeastward-flowing Guinea Current changes position with the seasons so that its northern limit lies at approximately latitude 7° N during the winter and latitude 15°N during the summer. The warm, highly saline Guinea Current reaches a depth of less than 660 feet (200 m) (Encyclopedia Britannica, 2017).The Guinea Current is a slow warm water current that flows to the east along the Guinea coast of West Africa with the presence of a seasonal upwelling which takes place along the equator. Similar to the Equatorial Counter Current in the Indian and Pacific Oceans, Gulf of Guinea is an area where the coastal upwelling has a real impact on local biological resources which stimulates phytoplankton growth Ali *et al*. (2011) and considered as Large Marine Ecosystem (LME) that includes sixteen countries namely: Angola, Benin, Cameroon, Congo, Ivory Coast, Democratic Republic of Congo, Gabon, Ghana, Equatorial Guinea, Guinea, Guinea Bissau, Liberia, Nigeria, Sao Tome and Principe, Sierra Leone and Togo.

The total length of coastline in the Region is nearly 7,600 km (Regional Project Coordinating Centre, 2003). Moreover, the signs of stresses are characterised by harmful algal blooms occurrence due to intense process of eutrophication linked to an excessive nutrient supplying in the Gulf of Guinea from anthropogenic sources (Figure 2.1). However, the Guinea Current flow is enriched by two sources: the North Equatorial Countercurrent (NECC) and the Canary Current. The seasonal variability of those currents can affect the seasonal variability of the Guinea Current. Furthermore, the presence of the trade winds at the equator strengthens the NECC, subsequently, the Guinea Current. In addition, during fall and spring there is a direct connection between the NECC and the Guinea Current. The thermocline is more close to the coast due to the intense current associated with surface cool water during boreal summer. Thus, the Guinea Current during summer is linked to the coastal upwelling and is weak for the winter time and strong for the summer period. Due to some variabilities in the Benguela Current, NECC, and Canary Current motions, the direction of the Guinea Current reverses during the minima, then, eastward weak winds was signaled for this period. These times are characterized by a Guinea Current speed high offshore and low onshore (Gyory *et al*., 2005).

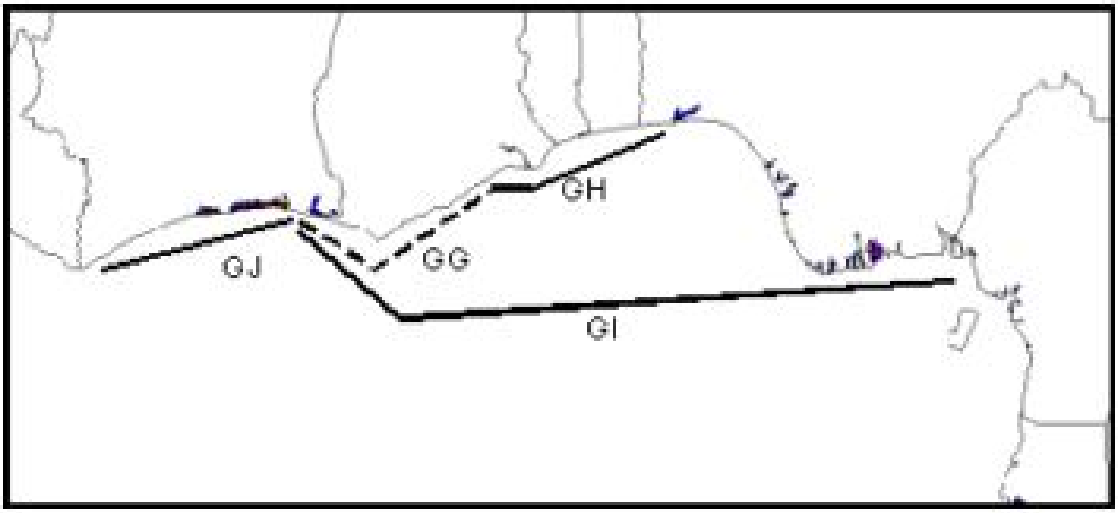


Figure *2* Plankton monitoring routes in the Gulf of Guinea (UNEP *et al*., 2013)

2.1.5.3 Supplying of nutrients and precipitation

Ramesh *et al*. (2014) reported that the process of eutrophication supplies aquatic plants, the nutrients for their growth: the major are phosphorus and nitrogen that accumulate in water bodies. These nutrients come from different sources such as groundwater, fluvial, and atmospheric through nitrogen cycle. Human activities have caused modification of the environment and altered hydrological cycles. Animal manures, and fertilizer applied in agriculture may accumulate in soil or transported from the land into surface waters or infiltrate into ground-waters; or rejoin the atmosphere (Mullins, 2009). The input of nutrients from run-off, the discharge of effluent from sewage works, agriculture, and industries, result in an eutrophic coastal waters high in nutrients. As a result of anthropogenic actions' nitrogen has doubled and phosphorus has tripled compared to natural values. Moreover, the pollution caused by nutrient enrichment affect coastal and oceanic environments (Ramesh *et al*., 2014). However, phosphate is in great amount through rainy season, whereas nitrate is high through dry season. The utilization of the land for farmland around riverine zones in Nigeria could be a justification for the large quantities of phosphate loading by the run-off over the rainy season (Adeyemo *et al*., 2008). Climate change affects the establishment and the amount of rainfall thereby would alter the pattern of freshwater run-off at the coastal plain watersheds levels and increase algae blooms (Kennedy *et al*., 2002).

2.1.5.4 **Sea surface temperature, salinity and winds**

Sea Surface Temperature (SST) is the temperature of the water in the surface layer of the ocean. Any change of temperature affects species communities' processes because temperature controls all their biochemical mechanisms (O'Connor *et al*., 2007). Over the last period, it has been demonstrated that temperature can be used to explain biogeographic patterns in marine systems and predicts the spatial change which happens in the composition and diversity of species. However, there are significant correlations between temperature and oceanographic parameters which influence species distributions across spatial scales (Wernberg *et al*., 2013). Therefore, because of the variation of water temperature, some species shift away from areas which have got too warm to areas cooler with a suitable temperature for their development (EPA, 2016). These shifts will have direct physiological effects on individual species depending on their thermal tolerance limits. Moreover, most of the shifts in species distributions have been recorded as responses to sea temperature rise (Wernberg *et al*., 2013). All marine species are poikilotherms. This means that the internal temperature of the species varies directly as a function of their immediate habitat. So, they are very sensible to any temperature disturbance (Akankali and

Elenwo, 2015). Temperature gradients are not the only ones that contribute to the extant biogeographic patterns.

Any changes in wind and temperature disrupt upwelling motion and the phytoplankton welfare, could be lowered. In some coastal areas, wind stress and density differences help the buoyancy and lead to water motions which carry marine species. When wind speeds are weak, food production is low but strong wind speeds drive the disaggregation of the food and participate in the development of the species. Wind stress and density differences help the buoyancy-driven to produce water motions which carry marine species (Kennedy *et al*., 2002). At smaller and large spatio-temporal scales, floating materials' dispersal patterns depend on wind speeds and directions, waves, the velocities and trajectories of the ocean currents. The distribution of the rafts is affected. Indeed, the changes in climate have eased invasions and introduction of species by modifying raft transport, by altering circulation patterns and prevailing wind directions. A shift in winds from onshore to offshore or vice-versa is likely to affect raft longevity (Macreadie *et al*., 2011). Regional understanding of wind variability is important for explanation of species dispersion along a given area.

Salinity is defined as the number of grams of salt per 1000 grams of water. So 1 gram of salt per 1000 grams of water is defined as 1 PSU (practical salinity unit). On the high seas, the salinity range is generally 32-37 psu or can be defined in ppt %. For instance, the mean salinity of the sea surface waters off the Sierra Leone coast is mainly less than 35.5 psu. Due to the inflow of freshwater, the surface of the zones near the coast is characterized by low salinity concentration. At 60–70 m depth, the salinity maximum is 35.7 psu and below

~ 500 m depth, the salinity decreases until it reaches minimum. Amount of salt in the ocean is constant but could be influenced by rainfall, run-off from land, and ice melt that diminish salinity by increasing water inputs. On the other hand, the process of evaporation enhances salinity which have an effect on marine species development. The North Atlantic is the ocean area the most saline. Salinity influences water density and could control ocean surface mixed-layer depth. This depth is a function of wind speed and sea surface cooling (Talley, 2002).

2.1.6 Effect of *Sargassum* presence

The unprecedented algae masses covered tourist beaches the most visited, filled bays and the seaside near the coast. *Sargassum* causes numerous environmental and economic problems. *Sargassum* beachings affect the biodiversity, biogeochemical cycling, life of the turtles, fisheries, also can form “dead zones” which means hypoxic or anoxic conditions (oxygen-deprived conditions in the water) in coastal ecosystems. *Sargassum* consumes all the oxygen and drives the suffocation of fish and aquatic organisms such as the turtles which are trapped in the huge mats of algae that constitutes their refuge.

The *Sargassum* is a niche of biodiversity, allowing the juveniles of many species such as fish, shellfish, turtles to grow while being fed and protected and, at the same time to be transported with fewer efforts. *Sargassum* constitutes a major problem for tourist beaches, since it starts to decompose after a few days (Hinds *et al*., 2016). Although *Sargassum* is non-toxic, but the unpleasant smell of its decaying attracts large number of flies on beaches to dry out. The dead organisms caught within the rafts release this awful smell and the poisonous hydrogen sulphide gas, which is harmful to most marine animals. The hydrogen sulphide gas can lead to several human health issues as the skin rash, nausea, headaches (See Table 2.1) when population is exposed to high concentrations in prolonged way. And even breathing difficulties if there is a prolonged exposure and can tarnish metals. Oxidation attacks the engines of fishing boats, reducing possible activity for some populations (Hinds *et al*., 2016).

Furthermore, decaying *Sargassum* trapped along the coasts create brown plumes in the water, which threaten the health of ecosystems depending on low oxygen content and high supply of nutrients. Indeed, Stranded *Sargassum* may reduce significantly beach attraction, even more so when *Sargassum* rafts entrapped anthropogenic materials like plastics and medical wastes. It can limit accessibility of the boat moorings and harbours to reach the coast without difficulty, and limit swimming and watersports such as surfing activities because, often *Sargassum* along the shoreline may be several metres thick (Hinds *et al*., 2016). Also, macroalgae beds form a substantial sink for CO_2 emissions, sequestering about 1 gigaton of carbon (GtC)/year (Jueterbock *et al*., 2013). So if they rot on the shore, they release all the amount of CO_2 before sequestrated into the atmosphere. The water quality is altered due to the decomposition of the algae and that has consequences on the fauna and the flora favoring the mortality of fish near the coast. Finally, the coverage generated by strandings prevents eggs from being spawned and makes it difficult; in some cases for the emergence of baby turtles on the beaches (Mazeas, 2014).

Table 1 Dose / effect relationship of hydrogen sulfide (H_2S) in humans

[H_2S](µg/m3)	**[H_2S](ppm)**	**Duration of exposure**	**Effects**
0.7-200	10^{-3}-0.1	<1 minute	Odor threshold
16 000-32 000	11.5-23	Several hours	Eye irritation
75 000-150 000	54-108	>1 hour	Irritations of ocular and respiratory mucous membranes
225 000-300 000	162-215.7	2-15 minutes	Loss of smell
750 000-1 050 000	539-755	<1 hour Several hours	Central nervous system involvement Possible Death
135 0000	970	<30 minutes	Severe systemic effects - Death in less than one hour
2 250 000	1618	15-30 minutes	Death
2 700 000	1942	Immediate	Death

Source: (Raghoumandan, 2011)

2.1.7 Ocean colour and chlorophyll

As reported by IOCCG (2008), remote sensing of ocean colour is a radiometric science, based on a defined spectral reflectance at the sea surface. Ocean Colour remote sensing was designed to produce synoptic views of phytoplankton biomass indicated as chlorophyll. Furthermore, to realize the photosynthesis, the species capture only the visible wavelength of the solar spectrum through the chlorophyll molecules which absorb and scatter sunlight and influence the fluxes over the sea surface. The intensity and wavelength of the flux may be quantified using remote sensing machines. The results of ocean colour obtained after several studies have revolutionized the field of biological oceanography and to coastal management. Also, near the shores the ocean colour data can be used to analyse sea surface conditions that the clarity of affect water such as run-off' sediment, upwelling occurrence that activate blooms. Hence, ocean colour data is a paramount tool to get a better understanding of how the oceans' species react to climate variability and forcing, to their future change due to the global climate alteration.

With μg/l as unit, chlorophyll is a colour phytoplankton, plants and algae pigment, implicated in photosynthesis as a photoreceptor which captures sunlight energy. There are six different chlorophylls forms identified as being a, b, c, d, e and f which correspond to different ranges of green wavelengths. From land plants to algae the chlorophyll a (chl_a) is the one responsible for the photosynthesis activities. In addition, as all phytoplankton have chlorophyll a (chl_a), chlorophyll sensors which rely on fluorescence to estimate phytoplankton presence can be used to detect the species in-situ to monitor and record immediate or long-term data. However, it cannot be used to identify specific species. Chlorophyll sensors rely levels based on chlorophyll concentrations in a sample of water zone. Thus, fluorescence may be measured to identify how much phytoplankton concentration contained in a water sample (FONDRIEST, 2014). Therefore, the maps of chlorophyll show the amount of chlorophyll in milligrams per cubic meter each month in the seawater (NASA, 2017). So, the study of ocean colour contributes to a better comprehension of species blooms and their influence on the environmental system.

2.2 Species Presentation

Large brown seaweeds (Phaeophyceae) are a various and complex marine species found in the littoral, in the shallow sub-littoral of marine environments according to Smale *et al*.(2013). *Sargassum* from Sargassaceae family and order of Fucales represents the most common species of brown macroalgae in tropical to warm temperate waters particularly in the northern hemisphere. The pelagic *Sargassum* is found in subtropical and tropical areas of both northern and southern hemispheres. It is common in South America, Australia, Africa especially in West Africa. The plant species body is diploid (2n) except the antherozoids and eggs haploid (n). *Sargassum* species are differentiated into root, stem and leaves. *Sargassum* lives free-floating at the sea surface and reproduces by fragmentation which gives a new individual like the mother because the younger region is separated from the old one; that means *Sargassum* cells are totipotent, able to regenerate any part of its anatomy. Multiplying by this method, *Sargassum fluitans* and *Sargassum natan*s use their separated regions to grow and develop into sea (Guiry and Guiry, 2011, 2013) cited in Sankare *et al*. (2016) and depicted by Addico and DeGraft-Johnson (2016) and Koffi *et al*. (2016).

2.3 Review of other Literatures

Zhong *et al*. (2012) used two ocean model configurations (Regional Ocean Modelling System (ROMS)) to investigate the dynamic mechanisms which lead to the distribution of the species on sea surface and to validate their results with those obtained with satellites observations in the Gulf of Mexico, West Atlantic Ocean. Then, they reported that in the ocean, a depiction of the transport pathways requiring Lagrangian observation under drifter trajectories and biological tracers could help to understand the physical processes integrated in the distribution of *Sargassum* species (Phaeophyceae), which is a macro-algae found in the Caribbean, Gulf of Mexico and North Atlantic and provided an appropriate habitat for several aquatic species and depended on local wind direction. Moreover, they studied *Sargassum* and *Trichodesmium* to explain the role of geostrophics processes on their distribution over sea surface. Those species which accumulated on sea surface were visible using satellite imagery. Thus, their patterns did not look like the distribution observed with the utilization of passive tracers within quasi-geostrophic turbulence. Then, the researchers examined the behaviour of the vortices inside sub-mesoscale range and found that the ageostrophic processes produced high divergence and convergence zones responsible for the implementation of areas where these species accumulate. Also, that the ocean was governed by these processes. The species were concentrated in the convergence zones after being expelled from the mesoscales eddies centre. That was justified by the satellite images observations. Finally, according to the authors we can track convergence and divergence processes on ocean surface by following *Sargassum* movement.

Feagin and Williams (2008) reported that each year between May to August, there is the wide arrival of *Sargassum* in piles along the beach on Galveston Island in Texas *Sargassum* deposits near the high tide line each year from May to August. The objectives were to determine how to rake the *Sargassum* affected birds and fauna, to assess *Sargassum*'s elevation variation and to investigate the nutrients contained in *Sargassum* furthering the growth of beach plants. Their methodology was based on a sampling of *Sargassum*'s elevation over two (2) years at third times on the unraked and raked beaches of Galveston island and with the techniques of the grooming, relocation, they assessed the cleaning of the beach. The analysis was to test the variation of elevation in the transects, to compute the variance and they used the software SPSS. After, statistical analysis, they indicated that there were no significant differences between Raked and Unraked. The only difference was noticed during 2006-2007 period and there was the presence of nitrogen and phosphorus through the comparison of their P-value between unwashed and washed *Sargassum.* Thus, most pelagic species that used the *Sargassum* for habitat would die once it reached the beach and that deposit of *Sargassum* at the base of the dunes further their growth but the researchers did not demonstrate how *Sargassum* nutrients were able to initiate plants growing.

Széchy *et al*. (2012) reported that *Sargassum fluitans* and *Sargassum natans*, had pattern distribution which lined up in rows following the winds direction. These species looked similar in certain characteristics. The authors described and illustrated the morphology of *Sargassum natans* collected offshore on the northern coast of Brazil in the northeast to southwest (North Atlantic Ocean). Then, they collected samples from the sea after they recognized the specie direction. The collected samples were conserved at low temperatures in a freezer and transferred them to a formaldehyde solution at 4%. Moreover, three primary lateral branches, ten blades and ten air bladders were analyzed to describe the species morphology and characteristics. As results they got that the primary lateral branches that measured (25.0-)33.0(-47.0) cm in length were much branched, densely arranged and tangled. Also, spines which abruptly tapered were (320-)450(-680) µm in length and were present along their upper portions. Primary lateral branches had a cylindrical outline and measured around 1 mm in diameter in median portions. The blades were spirally attached to the branch axes by a short pedicel and were firm, simple, narrow and lanceolate with predominantly symmetrical bases and acute apices, measuring (1.9-)2.3(-2.8) cm in length and (2.5-)2.8(-4.0) mm in width. Midribs were visible but not prominent with a thickness of (230.0-)324.6(-400.0) µm. Margins of the blades were coarsely toothed with aculeate teeth, and measured (300.0-) 450.0(-750.0) µm in length. There were no cryptostomata on the blades, no receptacles. Air bladders measured (1.7-)2.2(-3.0) mm in diameter and were numerous along the axes and the branches of all others. Their pedicels were cylindrical, and measured (1.2-)2.1(-3.8) mm in length. In conclusion, based on these characteristics, the offshore pelagic species was identified as *Sargassum natans*. The Brazilian species were similar to the descriptions of *Sargassum natans* from the North Atlantic Ocean in the width and dentate margins of the blades even though the specimens from Brazil showed less extended blades.

UNEP *et al*. (2013) had for objective to bring *Sargassum* event at the level of the United Nations Environment Assembly in order to attract attention to the environmental communities on the severe impacts linked to *Sargassum* species strandings in West Africa and Caribbean States and to gather resources to face this new environmental issue. They reported that the causes of *Sargassum* species upcoming were defined as the North Equatorial Recirculation Region (NERR) off Brazil, the seasonal change of sea surface temperature due to climate change, enrich in nutrient that enhances the growth of *Sargassum,* and also the maritime traffic as a potential introduction vector. Furthermore, the authors affirmed that *Sargassum* species has impacted aquatic resources, fisheries, waterway, shorelines and tourism. It had negative impact on the socioeconomic livelihood of coastal communities. Besides the ecological and socio-economic impacts aforementioned above, *Sargassum* species provides shield for migratory species and constitutes nursery habitat for a vast array of invertebrate and fish species. Also, the need to implement regional cooperation on ocean governance which gathered interested countries and organizations to enhance their collaboration and share information and experiences through an on-line forum in Freetown Sierra-Leone. Together, they brought different experts from the countries affected by the events (Benin, Sierra-Leone, Nigeria, Côte d'Ivoire, Liberia, Senegal, Ghana, Guinea, and Togo) to implement some strategy to manage *Sargassum* event in West Africa. They concluded that the *Sargassum* events must be discussed at the upcoming United Nations Environment Assembly UNEA-2 Side Event.

Addico and DeGraft-Johnson (2016) reported that the arrival of the invasive brown seaweed *Sargassum* in the Western Region of Ghana was first noticed in 2009. *Sargassum* being highly tolerant to environmental parameters such as sunlight, salinity and temperature variations, was enabled to occupy a broad range of habitats. Therefore, *Sargassum* species reproduce sexually, only *Sargassum natans* and S*argassum fluitans* reproduce by fragmentation. The presence of these species affected negatively the biodiversity, the tourism and the coastal communities activities. The authors identified and determined the nutritional and toxicological components of *Sargassum*. Twenty-four samples were collected from six ares along the coast of Western Region of Ghana and analysed using an Atomic Absorption Spectrophotometer (AAS) 900T. Then, the results of their analyses indicated that the *Sargassum* specimens contained low amounts of nitrogen. But contained very high concentrations of nitrate and ammonia which are the nitrogen form used by the plants, associated with phosphates. This has made *Sargassum* a source of agricultural fertilizer. Also, they noticed considerable amounts of toxic heavy metals in the *Sargassum* that were implicated in both the growth and the plants' metabolism. The domestic and industrial wastes associated with oil and gas activities, and shipping traffic could have participated to the accumulation of heavy metal in their tissues. *Sargassum* could be used as bio-monitor to evaluate the health of coastal environments because heavy metals were able to induce human health diseases.

Komatsu *et al*. (2014) reported that floating seaweeds named as *Sargassum horneri* with high biomass play important roles in the offshore waters by hosting flora and fauna species and that, spatial distribution of these floating seaweeds is wide from Hokkaido Island to north Kyushu Island around East China Sea and central Honshu Island. Therefore, because of global warming, some changes in geographical distribution of these seaweeds along the north-western Pacific Ocean coast was observed. They affirmed, *Sargassum* species helped by the vesicles can float and sometimes stranded on beaches or transported offshore because of positive buoyancy by surface currents. In this specific zone, under vegetative reproductive form, the floating algae live their entire floating-life stage. Furthermore, the authors focused on *Sargassum horneri* which is very important in fisheries and biodiversity well-being, and they estimated the change in geographical distribution of S. horneri in the north-western Pacific as a function of global warming. They also discussed its influences on fishes as a function of floating S. horneri rafts. The authors collected information about geographical distribution of S. horneri in this area and the distribution of S. horneri along the coast. Then, they used monthly mean surface water temperatures in February and August as the minimum and maximum surface water temperatures in a year and six scenarios of global warming which contained data of the adjacent seas of the North-Western Pacific for determination of geographical distribution. They made a comparative analysis in considering the months February and August of the year 2000, and predicted future geographical distribution of S. horneri in 2050 and 2100 in monitoring the different variation of water temperatures in February and August. The writers concluded that rise in water temperature further extended the species distribution of S. horneri along the Chinese coast. They observed that in winter in 2100, warmer temperature promoted S. horneri to more areas from the north end in 2050 to the north-east coast of Hokkaido Island alao from northwards along the Kurile Islands in 2100 where S. horneri disappeared due to the increasing temperature of the water beyond 30^0C in August. This study estimated impact of the increasing of the water temperature on marine species in 2050 and 2100 through A2 models.

Gower *et al*. (2013) reported that during April to August 2011, images from the European Space Agency’s MERIS (Medium Resolution Imaging Spectrometer) instrument on the ENVISAT (Environmental Satellite) satellite showed a significant increase in S*argassum* off northern Brazil. According to historical records' *Sargassum* was from sea sargasso or gulf of Mexico but through MERIS satellite the authors have indicated that *Sargassum* was dispersed in a new area off northern Brazil. The satellite MERIS that had been used to observe *Sargassum* before was interrupted. The researchers then exploited the satellites Moderate Resolution Imaging to detect and track *Sargassum* with a more high frequency.

In addition, they performed times series to show the seasonal distribution of *Sargassum* through images from MODIS using MRE and MERIS using MCI. The images indicated a shift in the *Sargassum* distribution. Therefore, they suggested that the shift was led by a supplying of nutrients inputs from rivers. Through MERIS images, the authors have shown that with *Sargassum* times series it is possible to determine their seasonal and inter-annual variability and these can be monitored using the monthly composites of algae species at one degree spatial resolution covering the latitude range of 0^0 - 45^0 N and longitude range of 100^0-10^0W for the years 2005 to 2011 from April to September. This includes the area of the Sargasso Sea, the Gulf of Mexico, the Caribbean islands, the tropical Atlantic off northern Brazil and eastwards to the west coast of Africa. In summary, using satellite data alone, we can show by satellite image the distribution of *Sargassum* under rafts form which differs from *Trichodesmium* blooms that has short-life.

Hinds *et al*. (2016) study was aimed to provide update information on *Sargassum* influxes to Caribbean, to offer guidance on sustainable *Sargassum* management to solve the clean up issue, to understand this phenomenon and to implement solutions. They argued that in 2011, the shores of Caribbean islands and West Africa areas were invaded by brown marine algae *Sargassum natans* and *Sargassum fluitans* generally associated with the Sargasso Sea located in the North Atlantic Ocean. These species have the capacity to float freely along life cycle and their movement was linked to the ocean currents rotation and winds. Thus, the authors searched to understand the origin, causes, spatial and temporal patterns, management plan, in order to find economic potential of *Sargassum* species to implement and the best adaptive strategies. Several factors could contribute to the sustainable management actions supported by the development of a communication plan, the removal of *Sargassum* manually or mechanically. For them, when *Sargassum* species arrived either in few amounts, or inaccessible, or on zones not destined for the tourists, the population must leave *Sargassum* species to disappear by itself. Furthermore, they noticed that the causes of *Sargassum* arrival in the Caribbean were not exactly known. However through ocean models, satellite trackers, and adequate resolution satellite, the researchers demonstrated that oceanic currents rotation in the North Equatorial Recirculation Region (NERR) associated with warming ocean and increasing dump of nitrogen and phosphorus into sea water allowed fast *sargassum* growth. The frequency and volume of their strandings in variable quantities were considered as seasonal or inter-annual but it was not really certain that the influxes will occur every year. In Caribbean, *Sargassum* affected fish and turtles habitats, communities life, boats displacement, tourism activities, human health due to the long exposure to high hydrogen sulphide gas concentrations. Beyond that, researchers have revealed that *Sargassum* constituted a refuge and food source for several fish, invertebrates, bird species and help also to reduce beach erosion by the growth of shore plants. They could also be used as plant fertilizer, food supplements, biofuel, livestock, human and fish food and its products could be sold for economic value with the participation of the public, organisations, governments.

Vogel (2015) noticed in his work that the excess of *Sargassum* beachings in the Caribbean was from the Sargasso Sea located in the North Atlantic Ocean around Bermuda with 1000 km wide and 3200 km long holding up approximately 10 million metric tons of *Sargassum*. The influx of *Sargassum* in the area was led by the rise of the sea surface temperatures and the low winds also affected by ocean currents. In addition to what was cited above, the spreading of *Sargassum* has been linked to the increase of nitrogen into the oceans because of human activities and global climate change. Moreover, author reported that *Sargassum* is generally harmless to humans and animals under a natural un-polluted environment. When it washes ashore, the species within the seaweed begin to die and give off unpleasant smell. Thus, beach goers viewed *Sargassum* as a nuisance but the fact is that it is a natural event due to Mother Nature at work. This did not mean that they had to sit back and allow *Sargassum* to take over the beaches. It has a variety of uses like an excellent medium for use as landfill, like a way to combat the threat of beach erosion, as fertilizer and compost, as food for Asian people. Then, a web program was created to provide weather report in order to track, their movement. Also, the removal of *Sargassum* with mechanical rakes and cranes was done to remove sand and sand-dwelling critters. Therefore, they decided to use the manual methods and associated their efforts with the deeds of organization.

Gower and King (2008a) indicated that since Colombus' time, the origin, the important presence of *Sargassum* on sea surface has fascinated several entities. These researchers used satellite imagery from 2002 to 2008 to map the extent and migration of *Sargassum* species in the Gulf of Mexico and western Atlantic that was difficult before because of the lack of adequate sensor combination. Thus, the authors made a survey to global coverage from June 2002 to April 2008 and detected 'the floating pelagic algae of *Sargassum natans and fluitans*' by satellite images from Medium Resolution Imaging Spectrometer (MERIS at 709nm) using MCI (Maximum Chlorophyll Index). *Sargassum* species were at or just below the sea surface and were affected by the impacts of winds, waves and oceanic currents. According to them, *Sargassum* extended throughout the eastwards direction. Moreover, during the months of March, April, May *Sargassum* were in low amount and they have not observed *Sargassum* with MERIS satellite from the third month cited above to June.

According to Hu (2009) algorithms have been developed to detect certain phytoplankton on sea surface based on their unique optical properties. Indeed, The author reported that 300 m full resolution of MERIS (Medium Resolution Imaging Spectroradiometer) data and 1 km resolution of MODIS (Moderate Resolution Imaging Spectroradiometer, Terra/ Aqua) data have been used to identify extensive surface slicks which could be *Sargassum* in the Gulf of Mexico. However, the previous algorithms defined to detect these slicks were not specific to floating algae. Then, Hu has performed an algorithm called Floating Algae Index (FAI) which can be applied to multiple satellite sensors in order to map floating algae in various aquatic environments, also to remove atmospheric effects and then, to detect intense phytoplankton blooms. Furthermore, Hu presented the traditional methods (NDVI, EVI) used before to map surface vegetation, and has effectuated data comparisons to show the advantages of the FAI concept. Finally, he defined several examples of visualization of marine species using satellite images (from MODIS and Landsat-7/ETM+) and FAI concept in the Yellow Sea, East China Sea, North Atlantic Ocean, and Gulf of Mexico. The author corrected MODIS data by removing the molecular (Rayleigh) scattering effects, and converted the output to Rayleigh-corrected reflectance (Rrc).

The simulation consisted in comparing three indexes from imagery with known floating algae under different conditions, and then, the FAI algorithm was implemented to process MODIS data. Mainly, Hu used MODIS Level-0 data from the U.S. NASA GSFC, and processed them using SeaDAS 5.1 to generate Level-1b data. At the end, the FAI images revealed floating algae pixels; in comparison with FAI, the NDVI images showed more variability in the images and the EVI images presented some improvement over the NDVI images, but they were more sensitive than the FAI images to the changing environmental statement. Moreover, the author also used MODIS FAI imagery to visualize floating algae off Qingdao, China. He compared results from MODIS and Landsat data showing recurrent algae slicks in different areas of yellow sea in the East China Sea, *Sargassum* in the North Atlantic Ocean and Gulf of Mexico, and found out that all slicks identified in the MODIS FAI images appear on the Landsat FAI image, but some slicks can only be identified on the Landsat FAI image because of their small size. In summary, FAI is a better index than NDVI and EVI. In addition, the author suggested that Landsat data can complement the MODIS findings for small sized floating algae even though Landsat coverage is restricted to near-shore waters only about 100 to 200 km of the coast.

Massingue *et al*. (2005) worked on the zonation patterns of seaweeds and seagrasses providing ecological, food advantages for coastal zone in Nampula province in 2002. First of all, they collected data about the current, temperature, rainfall and tides ranges, then collected, mapped and determined the composition of species based on the frequency of the present or absence of the species through transects. At the end, temperature and water's salinity were measured. The results showed that the seagrasses and seaweeds were abundant in Nampula province. Also, satellite imagery provides an accurate seagrass distribution. The authors recommended the utilization of satellite image in several sectors to appreciate the species resources.

The goal of Sankare *et al*. (2016) was to describe and to map the *Sargassum* species along the Ivorian littoral in several areas through geographical location using GPS, transect and an interview conducted with riverine populations. From off northern Brazil, *Sargassum natans* and *Sargassum fluitans* have been found in Ivorian marine waters by ocean currents and tides. This also was proved by Oxenford *et al*. (2015) which demonstrated that the ocean currents involved in the transport of *Sargassum* from northern Brazil to the African coast are North Equatorial Current, against North Equatorial Counter Current, Canary Current and the Guinea Current. The North Equatorial Counter Current enriched *Sargassum* North of Brazil, they then move to the Canary Current. These two currents are the basis of the formation of the Guinea Current and caused enrichment at the same time of *Sargassum*. The Guinea Current in turn drains species in Ivorian marine waters in an east direction at about 3°N along the West African coasts. The researchers found *Sargassum* in abundance in May and June on the Ivory Coast beaches. The authors concluded that *Sargassum* extension takes place in May in all coastal waters. The extension would be induced by salinity, light, temperature and nutrients, but from June, a low salinity was observed in surface water and strength of waves have reduced affecting their capability of adaptation and their development in the Ivorian aquatic ecosystems.

According to Redmond *et al*. (2014) seaweeds *Sargassum* is brown macro-algae species in tropical to warm temperate waters. It is the most diverse of its genus. The species are floating and their reproduction occurs through vegetative fragmentation to certain optimal temperature, salinity, and light requirements, depending on local conditions and latitude. Constituted of several chemical substances, *Sargassum* was used for multiples of applications. Seedlings were cultured under appropriate light and temperature conditions in greenhouse tanks and ocean nursery where seeded frames are hung horizontally on rafts or long-lines. The authors found that most species grow between the range of 24–30 °C and any changes affect their development. Moreover, *Sargassum natans* have an optimal temperature range of 18–30 °C, the species at 12 °C were not capable to grow and above 30°C growth decreased. Optimal salinity ranges were found to be stenohaline around 36-42 ppt, without growing at 18 ppt or below. At light levels of 200-300 µmol m^{-2} s^{-1}, the growth rates of species were saturated. Finally, compare to *Sargassum natans, Sargassum fluitans* has higher growth rate under optimal growth conditions. They are considered like invasive species with several advantages and disadvantages.

Hanisak and Samuel (1987) assessed the growth rates of the pelagic species of *Sargassum* for a cultivation under natural and optimal temperature, salinity and light conditions in the waters of Florida, Bahamas, Caribbean. In collecting the species, they have effectuated some treatments for each one of the parameters considered. Multiple trends were remarked in the growth of these species to the changes in temperature, and salinity state. Between 24-30°C, growth rate was maximal for the majority of species; below that temperature range there were sharp decreases of growth. Temperature conditions would be in the optimal range. *Sargassum natans* and *S. pteropleuron* had a temperature range between 18- 30°C. However, for *Sargassum natans* and *S. fluitans* no growth was detected around 12°C. The pelagic species were stenohaline in addition to the temperature. They reacted to the salinity with an optimal salinity for growth of 36-42°/**00.** No growth of species happened below 18°/**00**. Salinity of 30°/**00** negatively affected growth rates of *S. fluitans* and *S. natans* which induced a lack of adaptation for them to grow in other areas where the salinity is weak.

Oyesiku and Egunyomi (2014) worked on identification of *Sargassum natans* and *Sargassum fluitans* in southwestern part of Nigeria in Ondo State precisely, Ajegunle-Erun-Ama coast (Lat. 06^0 19′ 32″N, Long. 04^0 30′ 32″E, altitude of 5 m) during April to July. They analysed the chemical component of *Sargassum natans* and *Sargassum fluitans* useful in the agricultural domain. Based on light microscopical studies, the 'wracks' on the beach was identified as *Sargassum natans* and *Sargassum fluitans,* differentiated by the morphological differences: *Sargassum natans* have spines on its air bladder and long stalk bladder whereas *Sargassum fluitans* is lacking and the short stalk with wing tissue around air bladder. Their results showed that *Sargassum natans* and *Sargassum fluitans* were composed of substances like protein, lipids, flavonoids and more that drove plants growth. They made the conclusion that the *Sargassum* from Ondo State had unique features over West Africa. Moreover, *Sargassum* was considered as a danger to both the fishermen and the aquatic species but could constitute a product economically useful.

Solarin *et al*. (2014) worked on identification of *Sargassum hystrix var fluitans* which affected the coast of Nigeria and the fish communities and researched on the chemical composition of *Sargassum* specie through proximate analysis for its use in agriculture in Nigeria. They collected the species between Latitude 6º 25'10.47''N and 5º 52' 9.95''N and longitude 3º 25' 9.94" and 4º 52' 9.95’’between Latitude 6º 25'10.47"N and 5º 52' 9.95"N and longitude 3º 25' 9.94" and 4º 52' 9.95’’, identified and analysed the species. For them, this invasion of S*argassum hystrix var fluitans* in Nigeria coastlines was linked to changes in the natural climate and weather patterns in North Atlantic associated with ocean circulation changes. Then, the results of proximate analysis revealed that *Sargassum* was rich in nutrition, pharmaceutical and mineral constituents and also it was beneficial for the beach and certain organisms.

Hinds *et al*. (2016) reported that *Sargassum* beachings occurred in the Caribbean, West Africa, and in some other areas, causing social and economic threats along the coasts through their location and their quantity. Although it is an ecosystem it constitutes a nuisance by stranding in excessive amounts on populated areas beaches. *Sargassum* decomposes onshore, emits hydrogen sulphide gas and releases an odour smelling as rotting eggs. *Sargassum* decomposition leads several environmental issues by attracting insects, smothering turtle nesting sites, killing sea turtles and fish and economic problems to the Guadeloupe. Thus, a long-term prediction of *Sargassum* blooms and strandings events would require a thorough bio-ecological understanding, oceanographic and climate data to implement forecasting models. At the end, the authors presented a prototype integrated *Sargassum* Watch System to monitor and track *Sargassum* in near-real time using satellite imagery through MODIS, floating algae index (FAI) or alternative FAI (AFAI), numerical models, HYCOM currents, sea surface temperature and surface colour patterns to detect *Sargassum* from space and predict the movement of the rafts.

CHAPTER THREE

3.0 MATERIALS AND METHODS

To fufill the objectives earlier outlined, this chapter clarifies how data were collected and the procedures used to analyze them in order to investigate and extract the desired insights. The instruments that were used for the collection of the data were enumerated following the research questions defined for the study.

3.1 Materials

The following were required for the study:

- Global Positioning System (GPS),
- Satellite images data,
- Interpreter,
- Structured questionnaire,
- Recorder,
- Analysis software such as R studio, Qgis, Java based Statistical Processor (JASP).

3.2 Methods

To attempt the aim of this research, Primary data were collected from population of respondents using questionnaire, from previous literatures and secondary data from satellite dataset. This part of the work described sampling method, the data collection method and data analysis.

3.2.1 Objective 1: to analyze the relationship between climate change variables and the distribution of algal species.

3.2.1.1 Data collection

Throughout the literatures the variables considered as linked to *Sargassum* distribution were the Sea Surface Temperature (SST), precipitation, wind speed and direction, ocean currents, salinity levels, amount of nitrogen-phosphorus. These parameters were selected based on the mentioned role they play in spatio-temporal distribution of *Sargassum* species according to Hanisak and Samuel (1987), Gower and King (2008b), Marmorino *et al*. (2011), and UNEP *et al*. (2013). So, to analyze the relationship between climate change variables and the distribution of these algae species, monthly mean values of these oceanographic parameters were collected for the period 2011 to 2016. But, because of a matter of non updated satellite nutrients data over the Nigerian coast and the difficulty to get stations data, the amount of nitrogen-phosphorus have not been considered in this study. We used data from three moored buoy sites of the Pilot Research Moored Array in the Tropical Atlantic (PIRATA) from 2011 to 2016 to include salinity, wind speed, u-wind, v-wind (https://www.pmel.noaa.gov/tao/drupal/disdel/), sea surface temperature were from http://ds.data.jma.go.jp/tcc/tcc/products/elnino/cobesst/cobe-sst.html, precipitation data from NOAA database and then the ocean currents data from NASA-Ocean Surface Current Analysis–Real Time (OSCAR) https://podaac.jpl.nasa.gov/dataset/OSCAR_L4_OC_1deg/

Table 2 **Summary of climatic and oceanographic data**

Lon	Lat	Record (Monthly)	SST (℃)	Wind_spd (m/s)	Wind_dir (u,v˚)	Precip (mm)	SSS (psu)	Ocean_cur (u,v velocity)
9^0E	2^0S	2011-2016						
2^0W	7^0N							

Source: Author's compilation, 2017

The Netcdf files were processed to make them usable for the considered analysis using the Climate Data Operator tool labelled as CDO. The data have been aggregated with the cdo operator 'mergetime' into times series for those which were under a single time file. After that, the obtained file data were bilinear interpolated to obtain a new horizontal grid. The sea temperature data file which was in Kelvin were converted to degree Celsius. Moreover, area of the study was extracted from the Netcdf data files by considering the field longitude and latitude coordinates edges using the cdo operator 'sellonlatbox'.

The final verification of the extent and dimension of the data files were performed in order to evaluate if the information have not been corrupted during the process. Finally, the data files were converted into text files format (.csv) in order to extract the numeric values contained in the Netcdf data. Thus, the results were arranged so that they were in appropriate dataframe which can be recognized and manipulated by the R packages for the data analysis.

3.2.1.2 Principal component analysis

The collected data were large. So, in order to reduce the size of the data without losing information, a powerful tool for analyzing several variables' behaviour was used. It was the Principal Component Analysis (PCA) which is a multivariate technique that analyzes a data set in which observations are depicted by several inter-correlated quantitative dependent variables (Ayeni and Soneye, 2013). This technique requires the data correlation/covariance be define to bring out the major information contained in the data, to represent them as a set of new orthogonal variables called principal components and to display the similarities between observations and variables.

First of all, the data table was converted into a I(observations) × J (variables) matrix X in order to be analyzed by PCA. The data were pre-processed before analysis. In the course of performing a principal component analysis, we calculated a score for each variable on a given principal component and computed correlations among variables which were summarized under a correlation matrix form. To explain the information of the original data, we looked at the Standard deviation, eigenvalue, eigenvectors, loadings and Cumulative Proportion of Variance of our result. Therefore, the importance of an observation for a component was obtained by the contribution of the observation to each component given by the associated eigenvalue. Then, to determine the statistical significance of the Principal Component's: varimax rotation method was used. Varimax rotation identified the variables that demonstrate high loadings for a given component, and what these variables have in common (Abdi and Williams, 2010).

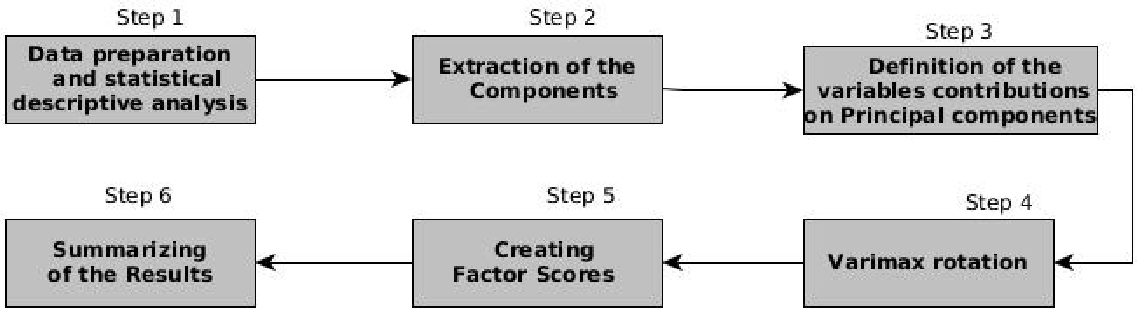


Figure *3* Principal Component Analysis Steps

FactoMineR, Factoextra, Ade4 packages and the function Prcomp of R statistical software are the most powerful R packages to perform a Principal Component Analysis. Those tools were explored and used to analyze our data table using R studio Version 1.0.143 "Single Candle". Thus, this analysis was performed to find the most important variables that lead to the distribution of *Sargassum* over sea surface as used by Siddiqi and Quaiser (2014).

3.2.2 Objective 2: mapping the spread of *Sargassum* distribution from 2011-2016 along the Nigerian coast

3.2.2.1 Data collection

The imagery coordinates were collected from scientific researches. GPS coordinates of *Sargassum* distribution along the West African coast (Ivory Coast, Ghana, Togo, Nigeria) to map ground-truth data from 2011 to 2016. Also, based on previous researches, the *Sargassum* upcoming covered certain seasons over years, that differ from one place to other.

Through the method of normalized Fluorescence Line Height (nFLH) obtained by dividing Fluorescence Line Height (FLH) by the cosine of the local solar zenith angle (Z), at the time of observation (NFLH = FLH/cos Z), the chlorophyll repartition of floating algae (*Sargassum* fluorescence) at the Nigerian coast was estimated. As advocated by Blondeau-patissier *et al*. (2014) Modis FLH have been effective in monitoring of *Sargassum* patterns in the Gulf of Mexico and the North Atlantic Ocean. According to Hu (2009) the design of Floating Algae Index (FAI) is similar to that for Modis FLH in removing atmospheric effects Gower and King (2012), to rate solar chlorophyll-a fluorescence, to signal excess algae blooms in the coastal ocean and to show up any spatial, seasonal occurrences of floating *Sargassum*. The efficiency of this approach has been also demonstrated by Hu and Feng (2016), Frolov *et al*. (2013) and Hu *et al*. (2005) in estimating floating algae in the coastal zones. Thus, monthly global composite Aqua Modis normalized Fluorescence Line Height (nFLH) data at 9 km spatial resolution from 2011 to 2016 was used. The range of the spatial coverage was taken between 2° to 7° latitude and 2° and 9° longitude.

3.2.2.2 Data analysis

First of all, the GPS coordinates collected from prior reviews were used to map *Sargassum natans* and *Sargassum fluitans* patterns helped by different pins colour in terms of concerned areas using Google earth 7.1.8. Then, Modis Aqua data obtained as level-3 standard products from the NASA Ocean Biology Processing Group (OBPG) were processed using Qgis and SeaDAS 7.4 software in order to reveal monthly variations in *Sargassum* patterns frequency. Also, among the 72 times series images downloaded, we selected the images less affected by aerosols, clouds and sun glint. The images were imported, reprojected with the masks defined and the pixels scales extracted.

3.2.3 Objective 3: to evaluate the perception of coastal residents about climate change impact on the occurrence of *Sargassum* species on Nigeria coastline

3.2.3.1 Survey method

To depict the perception of coastal residents on the presence of S*argassum* on the banks and their notion of climate change, a descriptive research design which involves analyzing the behavior of a subject in the accurate way without any influence (survey) was used, whereby quantitative and qualitative information were collected from two hundred and six (206) households heads or from persons who can answer the questions on behalf of the household's head. Based on random sampling, the household survey was conducted in eight (8) communities (See Table 3.2).

Questionnaire had been considered as data collection tool (Appendix A). By asking a set of questions at each of the surveys locations, the surveys were made to allow comparisons across several susceptible vulnerable areas to the *Sargassum* species upcoming and between diverse households' feelings. The questionnaire was structured in five (5) sections : Section A provides a view of the socioeconomic status and household characteristics of the respondents in order to describe and compare households across case study locations. Section B focused on awareness and perceptions of the impacts of climate change. Section C was aimed at the communities' perception on *Sargassum natans* and *Sargassum fluitans* occurrence to find out the extent to which households are affected. Section D sought the consequences of climate change and *Sargassum* species occurrence and livelihood challenges. Then, Section E, the existence of any adaptation measures about climate change and *Sargassum* occurrence implemented by the households communities.

Those zones were selected because of their location near the coast or near lagoons and streams to see if, according to Sankare *et al*. (2016) it could be possible to verify the presence of *Sargassum natans, Sargassum fluitans* in both areas types. In each location, after identifying households respondents, these one were interviewed. Moreover, the questionnaire was based on both closed and open-ended questions in order to get a precise, simple, logical and easy questionnaire to conduct. It began with easy questions that raised interest of the respondent. In addition, the questions explored how livelihoods had been impacted and how communities evaluate the surrounding changes, the signs of climate change in terms of productivity of their activities upon ocean, temperature variability, water pollutants supplying.

Speakers of local language were trained to help in data collection. Once the potential participants were identified, they were encountered with the help of the interpreters, who introduced, depicted the project, and asked them if they would like to participate in the project. It was clarified that there is no obligation to the respondents to take part if they do not wish to participate and the confidentiality of the responses. Also, if respondents were free to demand clarification in case of any incomprehension and were allowed to expand on the topics. The interviews were recorded with a recorder and field notes. GPS coordinates of the considered locations and some photographs were taken in order to enhance efficiently the observation process**.** Interviewing began in middle of may 2017 and was ended in June 2017. This period was covered with several trips to the survey sites, Some persons encountered were less willing to attend or to answer the questions, thus the final number of questionnaires administered was smaller than what envisioned (206 interviews administered).

Table 3 **Summary of the study location**

State	Local Government Areas (LGAs)	Community

	Ojo/ Otto-awori	Egan-oromi
		Etegbin
		Igboja
	Badagry/ Olohunda	Okogbo/ Olohi
Lagos	Agege/ Ilado-odo	Sea-beach, Idi-mango
	Apapa/ Amunwo odofin	Igbologun (Snake island)
	Lekki	Eleko Beach

Source: Field data, 2017

3.2.3.2 Data analysis

Once data collection was completed the answers from the questionnaire were processed in a statistical software such as the standard statistical program Libre Office Calculator version 5.1.6.2 in Ubuntu exploitation system which is similar to Microsoft Excel 2010 in Windows exploitation system for the data preparation and coding (then, transferred in JASP Version 0.8.1.2 statistical software for analysis). The qualitative data were processed and analyzed in the statistical software Rstudio Version 1.0.143 integrated development environment through the package 'R-based Qualitative Data Analysis package called 'RQDA' (Huang, 2014) cited by O'Keeffe *et al*. (2016). RQDA is a new open source with computer-assisted qualitative data analysis capabilities which allow for thematic analyses of survey information. Throughout the interviews and whilst examining the obtained transcripts, a number of words or of phrases came out several times as being important. These words were coded and allowed a commonality of the words in order to evaluate the relationship between them. Then, the significant portions of the quantitative data were statistically analysed to assess the different points of view of the participants within the three states O'Keeffe *et al*. (2016). RQDA analyses were performed according to Chandra and Shang, (2017) described steps:

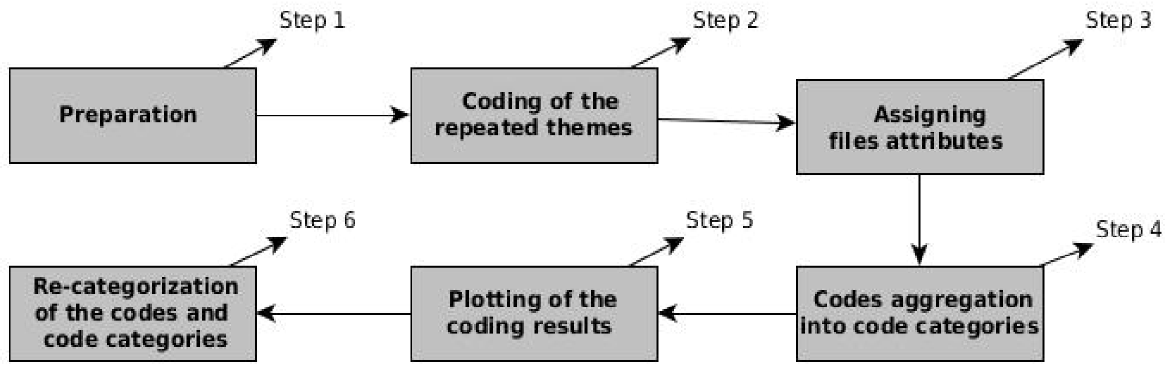
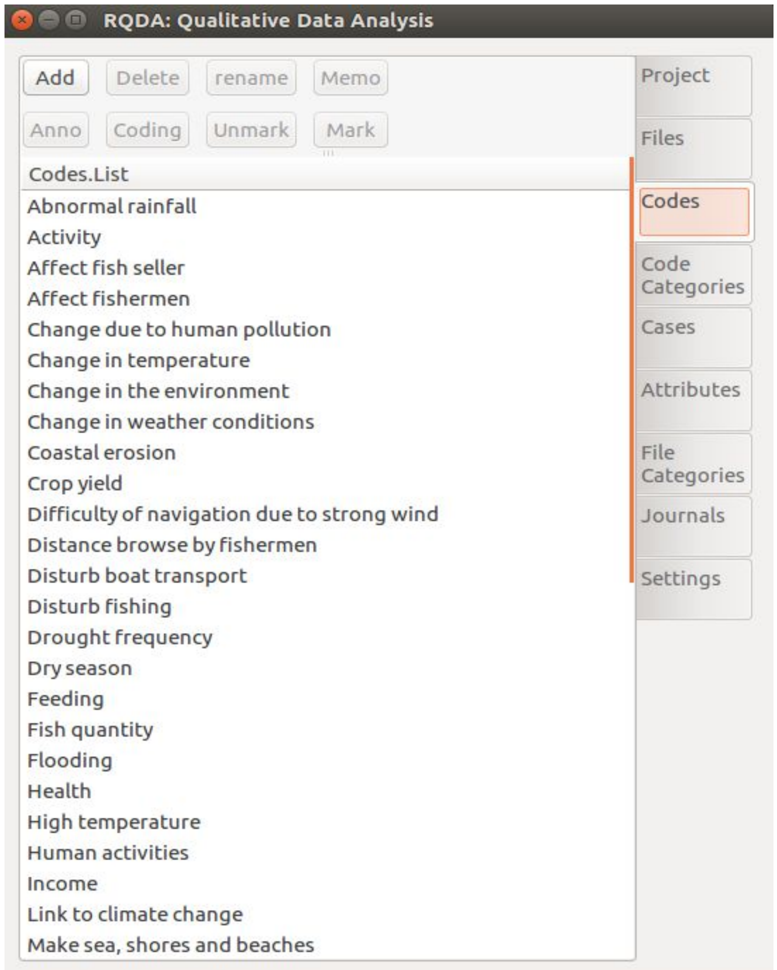


Figure *4* Methodological workflow of qualitative analysis

In Rstudio, using the RQDA interface (Figure 3.3) this workflow were handled to extract the frequencies of the codes and codes categories contain in the administered interviews.


RQDA: Qualitative Data Analysis
Add
Delete
rename
Memo
Anno
Coding
Unmark
Mark
Codes.List
Abnormal rainfall
Activity
Affect fish seller
Affect fishermen
Change due to human pollution
Change in temperature
Change in the environment
Change in weather conditions
Coastal erosion
Crop yield
Difficulty of navigation due to strong wind
Distance browse by fishermen
Disturb boat transport
Disturb fishing
Drought frequency
Dry season
Feeding
Fish quantity
Flooding
Health
High temperature
Human activities
Income
Link to climate change
Make sea, shores and beaches
Project
Files
Codes
Code Categories
Cases
Attributes
File Categories
Journals
Settings

3.2.4 Objective 4: to examine the past trend of the major variables that drive *Sargassum p*henomena along the Nigerian shores.

3.2.4.1 Data collection

From the principal component analysis results, the parameters considered as the most important, leading to *Sargassum* patterns were extracted from different website and for different times series length because of the oceanic data availability and accessibility difficulty. The monthly precipitation data and sea surface temperature (SST) data from 1981 to 2016 were downloaded from NOAA/OAR/ESRL website at http://www.esrl.noaa.gov/psd/, the ocean current U-velocity, V-velocity components provided by NASA-Ocean Surface Current Analysis–Real Time (OSCAR) from 1993 to 2016 http://www.oscar.noaa.gov. Sea surface salinity (SSS), wind speed, u-wind and v-wind were downloaded from he Pilot Research Moored Array in the Tropical Atlantic (PIRATA) from 1998 to 2016. All the variables were monthly data and were extracted over 7^0N - 2^0S to 2^0E - 9^0W zone.

The Netcdf files were processed to make them usable for the considered analysis using the Climate Data Operator tool labelled as CDO. The data have been aggregated with the cdo operator '*mergetime'* into times series for those which were under a single time file. After that, the obtained file data were bilinear interpolated to obtain a new horizontal grid. The sea temperature data file which was in kelvin were converted in degree Celsius. Moreover, area of the study was extracted from the Netcdf data files by considering the field longitude and latitude coordinates edges using the cdo operator *'sellonlatbox'*.

The final verification of the extent and dimension of the data files were performed in order to evaluate if the information have not been corrupted during the process. Finally, the data files were converted into text files format (.csv) in order to extract the numeric values contained in the Netcdf data. Thus, the results were arranged so that whether they were in appropriate dataframe which can be recognized and manipulated by the R packages for the data analysis.

3.2.4.2 Data analysis

A trend is a significant change over time exhibited by a random variable, detectable by statistical parametric and non-parametric procedures (Longobardi, 2009). Using studio Version 1.0.143 "Single Candle" we performed a time series analysis. Thereafter, removing the missing data contained in the data set, we deseasonalised them to observe the different components patterns contained in the data and to isolate the influence of the independent variables. The time series were decomposed into data, seasonal, trend and remainder (errors) components using moving averages with multiplicative seasonal component to determine the trend component from the time series. Furthermore, the seasonal plots were computed for each time unit, by averaging the variances values over all the periods. The error components were determined by removing trend and seasonal from the original time series. Moreover, the test of autocorrelation was performed to evaluate the variables' autocorrelation, then through the method of Prewhitening (PW) yuelipon according to Yue *et al*. (2002):

$$Y_t = X_t - r_1 X_{t-1} \quad (1)$$

With

$$X_t = \mu_x + \rho_1 (X_{t-1} - \mu_x) + \varepsilon_t \quad (2)$$

Where μ_x is the mean of X_t, ε_t is the white-noise process with mean $\mu_\varepsilon = 0$ and variance $\sigma_\varepsilon^2 = \sigma_x^2 (1 - \rho_1^2)$ in which σ_x^2 is the variance of X_t, the white-noise (variability) contained in the dataset were removed to reduce the occurrence of bias in the detection of long-term trends. The trend test and its p-value analysis were used to estimate the probability of the trend. Thereafter, trend quantification with the least squares linear regression analysis was done to define the magnitude (slope) of the change in time.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

This chapter presents and discusses the results of the data analysis in response to the research questions defined in chapter one. The results presented with plots, graphs and tables depict: the relationship between climate change variables and *Sargassum* distribution; the bloom time series of *Sargassum* distribution, the perception of coastal residents on the presence of *Sargassum* and their knowledge about climate change; and the potential trends of the climatic and oceanographic parameters influencing the *Sargassum* shift.

4.1 Analysis of the Relationship between Climate Change variables and the Distribution of Algal species.

This section presents results for objective 1 of the research. After having scaled, centered, rounded the dataset because of the units differences, we got an adjusted dataset. Then, the results of the rotation varimax presented in Table 4.1 gave us a new reduced dataset easier to study and determine the major principal components. Table 4.1 shows the significance test of the data based on Kaiser-Meyer-Olkin (KMO) and Bartlett test of sphericity which measures data adequacy. Thus, Bartlett test is less than 0.5 and KMO index is over 0.62 meaning that the data is more adequate and appropriate to a principal component analysis.

Table 4 **Kaiser-Meyer-Olkin and Barlett test for Significance test and oceanographic parameters' adequacy with R function**

Kaiser-Meyer-Olkin factor adequacy

Call: KMO(r = c)
Overall MSA = 0.62
MSA for each item =

Salinity	SST	Precip	U-velocity	V-velocity	U-wind	V-wind	W-spd
0.61	0.50	0.50	0.50	0.48	0.81	0.65	0.64

Bartlett
chisq = 397.4039 p.value = 6.55253e-67 df = 28

Source: Author's computation, 2017

Moreover, the relationship between the variables is illustrated by the correlation matrix illustrated in Figure 4.1. From the result, the correlation varies with the colour. Light colour represents weak correlation while strong or dark colour represents strong correlation. The correlation could either be positive or negative. Negative correlation is depicted with red while positive correlation is depicted with blue. The areas of the circles represent the absolute value of the corresponding correlation coefficients and bounds size design the confidence interval matrix. The intensity of the relationship is presented in the chart correlation matrix (See Figure 4.2) which shows on top side the absolute values of the correlation plus the result of the Bartlett test as stars. At the middle, the histogram of each variable shows the frequency of occurrence of the values present in the data. On the bottom side the bivariate scatterplots with a fitted red line depict data distribution as a function of the relationship between them. Then, when the relationship is weak, the dots are more loose but show a tendency for the y axis variable to either increase or decrease as the x axis variable increases.

Furthermore, Figure 4.1 and Figure 4.2 is the result of oceanographic parameters correlations. The figure shows the strength and sign of the existent correlation between the variables. Thus, a strong positive correlation (=1) exist between wind speed (W-spd) and each of the component of the wind direction (U-wind, V-wind). U- velocity and V-velocity which design the ocean currents aspects are negatively correlated (~ - 0.6), also V-velocity is strongly negatively correlated (~ - 0.8) with sea surface temperature (SST) and moderately negatively correlated with salinity (between - 0.4 to - 0.6). It could also been seen from the figure that positive moderate correlation existed between U-velocity and the salinity (~ 0.6), and a negative correlation (~ - 0.2) more or less low with sea surface temperature (SST). SST has moderate negative correlation (between - 0.4 to - 0.6) with the precipitation, and low negative correlation (< - 0.2) with W-spd, U-wind and V-wind, then SST has low positive correlation (< 0.2) with salinity and U-velocity. Finally, salinity has moderate positive correlation (0.4 - 0.2) with the precipitation and meridional wind component (V-wind), and more or less positive correlation with W-spd and U-wind (~ 0.2).

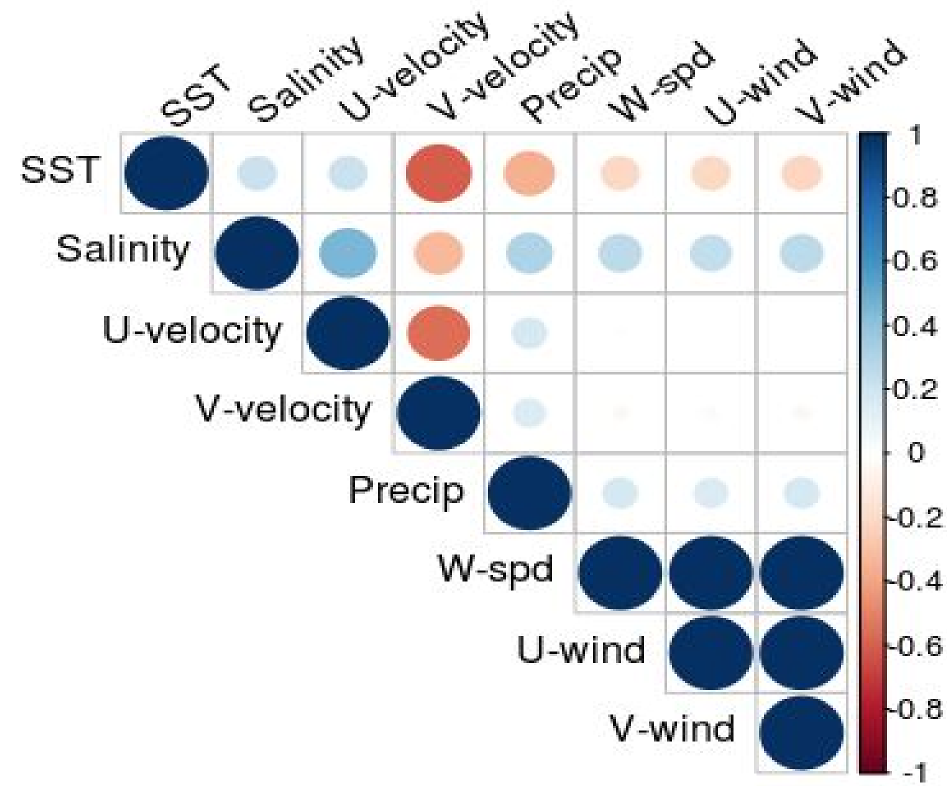


Figure 6 Correlogram matrix of the oceanic variables between 2011 to 2016

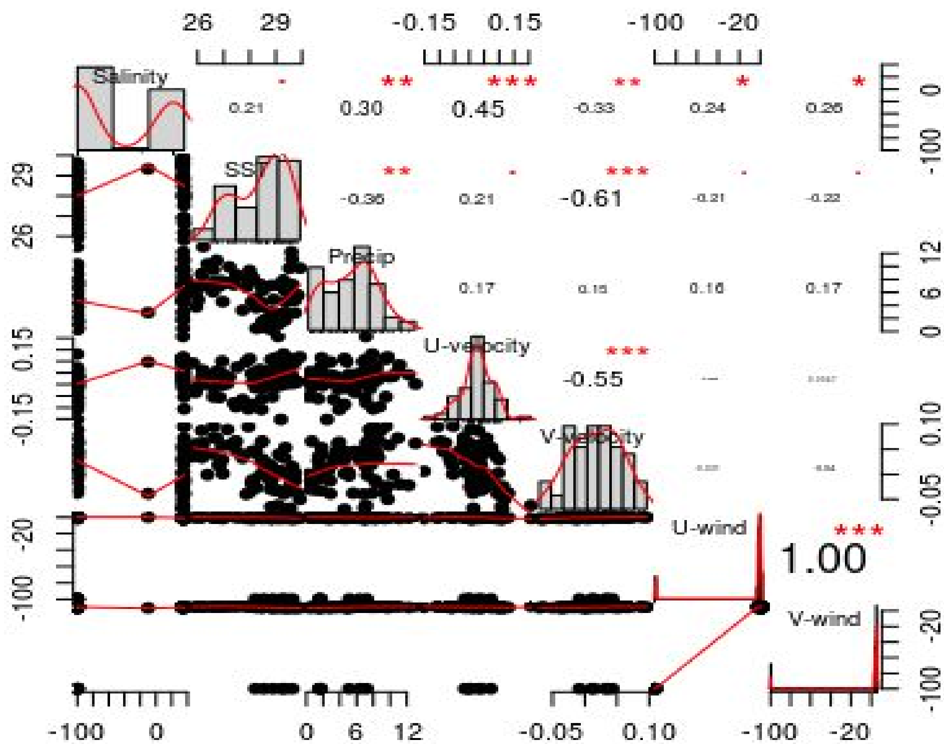


Figure 7 Chart' correlation matrix of the oceanic variables between 2011 to 2016

Table 5 **Principal component matrix of eigenvalues less than 1 (8 components extracted) and its importance.**

Principal components

Standard deviations (1,…, P=8):

1.793	1.482	1.148	0.768	0.662	0.487	0.029	0.0027

Rotation (n * k)= (8 * 8):

	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8
Salinity	-0.208	-0.406	0.34	0.613	0.499	0.22	0.012	0.0003
SST	0.159	-0.481	-0.365	0.42	-0.346	-0.557	-0.014	0.001
Precip	-0.181	0.048	0.726	0.119	-0.644	-0.079	0.01	0.001
U-velocity	-0.046	-0.5	0.328	-0.607	0.286	-0.432	-0.008	-0.001
V-velocity	0.014	0.59	0.172	0.243	0.359	-0.657	-0.018	-0.001
U-wind	-0.544	0.022	-0.177	-0.034	-0.027	-0.088	0.813	0.01
V-wind	-0.547	0.017	-0.162	-0.03	-0.032	-0.055	-0.42	0.701
W-spd	-0.547	0.016	-0.162	-0.028	-0.033	-0.056	-0.401	-0.712

Importance of components:

	Comp.1	**Comp.2**	**Comp.3**	**Comp.4**	**Comp.5**	**Comp.6**	**Comp.7**	**Comp.8**
	1.793	1.482	1.148	0.768	0.662	0.487	0.029	2.748e-03
Proportion of Variance	0.401	0.274	0.164	0.073	0.054	0.029	0.0001	9.441e-07
Cumulative Proportion	0.401	0.676	0.841	0.915	0.970	0.999	0.999	1.000e+00
Eigenvalues								
Variance	3.215	2.197	1.319	0.591	0.439	0.238	0.001	0.000
% of var.	**40.188**	**27.461**	**16.485**	7.392	5.488	2.974	0.011	0.000
Cumulative % of var.	40.188	67.649	**84.135**	91.526	97.015	99.989	100.0	100.0

Source: Author's computation, 2017

Table 6 **Varimax rotated component loading matrix, eigenvalues, total variance and cumulative variance**

Varimax rotated components

Call: principal(r = PCA_data, nfactors = 3, rotate = "varimax")
Standardized loadings (pattern matrix) based upon correlation matrix

	PC1	PC2	PC3	h2	u2	com
Salinity	0.22	**0.78**	0.03	0.66	0.3340	1.2
SST	-0.18	0.29	**-0.81**	0.77	0.2315	1.4
Precip	0.07	0.47	**0.76**	0.81	0.1926	1.7
U-velocity	-0.06	**0.83**	-0.12	0.70	0.2990	1.1
V-velocity	-0.05	**-0.60**	**0.66**	0.81	0.1948	2.0
U-wind	**0.99**	0.06	0.07	1.00	0.0035	1.0
V-wind	**0.99**	0.07	0.08	1.00	0.0019	1.0
W-spd	**0.99**	0.07	0.08	1.00	0.0019	1.0

	PC1	PC2	PC3
SS loadings	3.045	1.97	1.71
Proportion Var	0.38	0.25	0.21
Cumulative Var	0.38	0.63	0.84
Proportion Explained	0.45	0.29	0.25
Cumulative Proportion	0.45	0.75	1.00

Test of the hypothesis that 3 components are sufficient.
The chi square statistic is 430.82 on 7 degrees of freedom. The p-value is 5.83e-89
*h2: variable variation *u2: variation error *com: communality

Source: Author's computation, 2017

From the result in Table 4.2, few components accounted for a great proportion of the total variances shown by the eigenvalues and principal components (eigenvectors) of the correlation matrix, the largest correlations are in boldface. The result in Table 4.3 presented that of the 8 components, only 3 were significant in assessing *Sargassum* species distribution after applying the varimax rotation and determined the importance of each of the three (3) principal components. This was also justified by the screeplot in the Figure 4.3 that suggest that where the last large break appeared the components before that accounted for the most important variance.

The result of the varimax rotation revealed the percentages of the total variances of the three (3) principal components extracted, that, together explain 84.135% of the total variance of the variables with 40.188% for the first, 27.461% for the second and 16.485% for third principal components. Moreover, the selected components are characterized by their high loadings. The loadings plot presented in Figure 4.4 summarized the variables properties and gave the patterns among their relationship. The variables are gathered as a function of the components with which the loadings of each component are in relation. Thus, this was deduced from the results presented in the Table 4.3 and Figure 4.5 :

- First component : U-wind, V-wind and W-spd

- Second component : V-velocity, U-velocity, Salinity and SST

- Third component : Precip, SST and V-velocity

Following the method of Ayeni and Soneye (2013) the results obtained show that the variables in first component had strong positive loading. Of the 3 variables in the second component, V-velocity had a strong negative loading, U-velocity and Salinity had a moderate positive loading. Hence, of the three (3) variables in the third component, Precip had a strong positive loading, SST had a strong negative loading and V-velocity had a moderate positive loading (See Figure 4.4). For the first component, this means that these three parameters vary together. If one changes, then the remaining ones tend to as well. This component can be viewed as a measure of 'the wind circulation'; it may interpret the principal source of the variation which occur in the set of data altering *Sargassum* species distribution.

The first principal component is named wind patterns circulation, this could mean that the wind pushes ocean water in the direction where it is blowing and drives *Sargassum* rafts on their way. Furthermore, the second principal component can be viewed as a measure of 'the thermohaline' which link the oceanic currents (defined as u-velocity and v-velocity, the difference between the sea surface salinity and the sea surface temperature. It may interpret the second important source of the variation occurring in the set of data with a considerable contribution according to loadings and varimax rotation results. As a result of disturbance in the sea surface temperature and the sea surface salinity concentrations, in the wind patterns, in the current velocity associated with the upwelling process (which bring nutrients for algae growth) and in the ocean circulations patterns the *Sargassum* species distribution around the coasts have been affected these last years. Similarly, Tanaka and Fosca (2003) cited by Solarin *et al*. (2014) reported that the *Sargassum* masses were deposited along the coasts by the currents and winds patterns and then, that the *Sargassum* invasion along the Nigerian coast was driven by the North Equatorial Counter Current (NECC) derived current motion named Guinea current and Canary current motion. Then, the third principal component can be viewed as a measure of 'the evaporation' meaning that fresh water from precipitation mixes with the ocean water, dilutes salt amount and reduces the water density and the current velocity. This phenomenon of evaporation is considered high in the coastal area, thus the increase in air humidity over ocean's surface and the presence of the clouds diminish the direct solar radiation which increases sea surface heat exchange. That implies the reduction of the evaporation phenomenon which could affect the water density and have repercussions on how the *Sargassum* species could be transported at which speed, at which season, knowing that heating and excess precipitation have the opposite effect.

Thus, Zhong *et al*. (2012) demonstrated that in the Gulf of Mexico at the ocean surface the strong horizontal divergence and convergence zones due to ageostrophic processes (ocean circulation, wind-driven, currents) led to floating algae accumulation lines which justified the satellite image of the distribution of *Sargassum* patterns. Also, based on the such things as ocean currents, wind patterns, the arrival season, size and intensity of the upcoming *Sargassum* species in Texas coast Frazier (2014) demonstrated that it is possible to approximate its arrival in the *Sargassum* loop system. Also, according to Redmond *et al*. (2014) *Sargassum* species are more stenohaline, with an optimal salinity range of 36-42 ppt, a light saturation for growth at 200-300 µmol m^{-2} s^{-1} photons flux densities and a optimal temperature range of 18-30^0 C (*S.natans*) and 24-30^0 C (*S.fluitans*). Any disturbance in these parameters affected *Sargassum natans* and *Sargassum fluitans* growth conditions. In conclusion, wind circulation, thermohaline patterns and sea surface temperature can be define as the principal oceanographic parameters that have direct effect on *Sargassum natans* and *Sargassum fluitans* distribution patterns along the coasts.

The result of variables plot analysis is shown in Figure 4.4. According to the result, the orthogonal origin indicated the global average of the parameters. The result also showed that the arrow length, wind speed and wind direction (u, v) had strong influences (with a contribution more than 15) on the *Sargassum* species distribution; only the precipitation did not change significantly (with a contribution around 5), thus its influence could be considered as minimal compared to other oceanographic parameters which presents a considerable arrow length. But, the precipitation patterns is evolving with the wind patterns in a positive trend as demonstrated by (Huth and Pokorna, 2005), a major part of rainfall occurrence trend were mostly linked with the meridional wind component and the rainfall amount.

Parameters with long arrow length indicated that their influences were maximum. In addition, with a contribution of approximately 13, v-velocity evolves with sea surface temperature (SST), u-velocity and sea surface salinity but in the opposite way. These evolve together with a negative trend for the sea surface temperature (SST) patterns while u-velocity and sea surface salinity have a positive trend and account for a contribution of approximately 10. Moreover, the distribution of *Sargassum natans* and *Sargassum fluitans* were highly correlated with these oceanographic variables specified as being wind patterns (u-v wind, wind speed), currents oceanic (u-v velocity), sea surface salinity and sea surface temperature. The first axis (Dim 1) depicted 40.2% of the variation in the dataset whereas the second axis (Dim 2) depicted 27.5%. The two Dim (principal component) were responsible for 67.7% of the variation in the data, meaning that they highly impacted *Sargassum* species distribution. Also, the separation between the arrows corresponded to the different roles they play in the shift and in the patterns of *Sargassum* species. Finally, Figure 4.6 shows the contribution of the parameters to each of the principal components which intervene in the process.

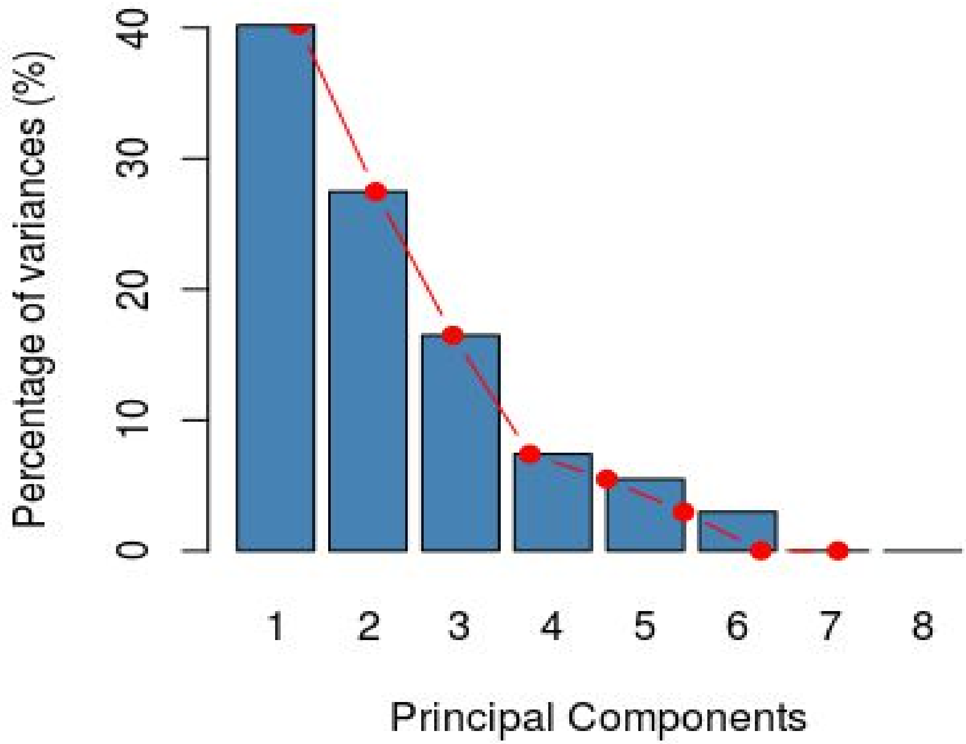


Figure 8 Screeplot of the variables' variances against the number of the principal components

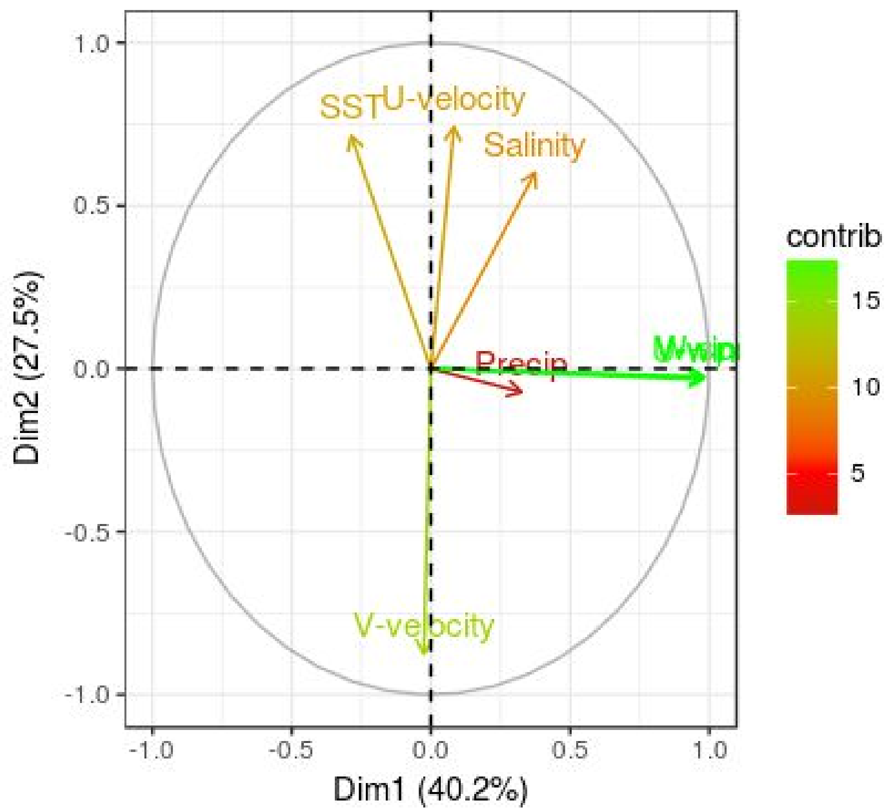


Figure 9 PCA biplot diagram of oceanic variables based on the first two components

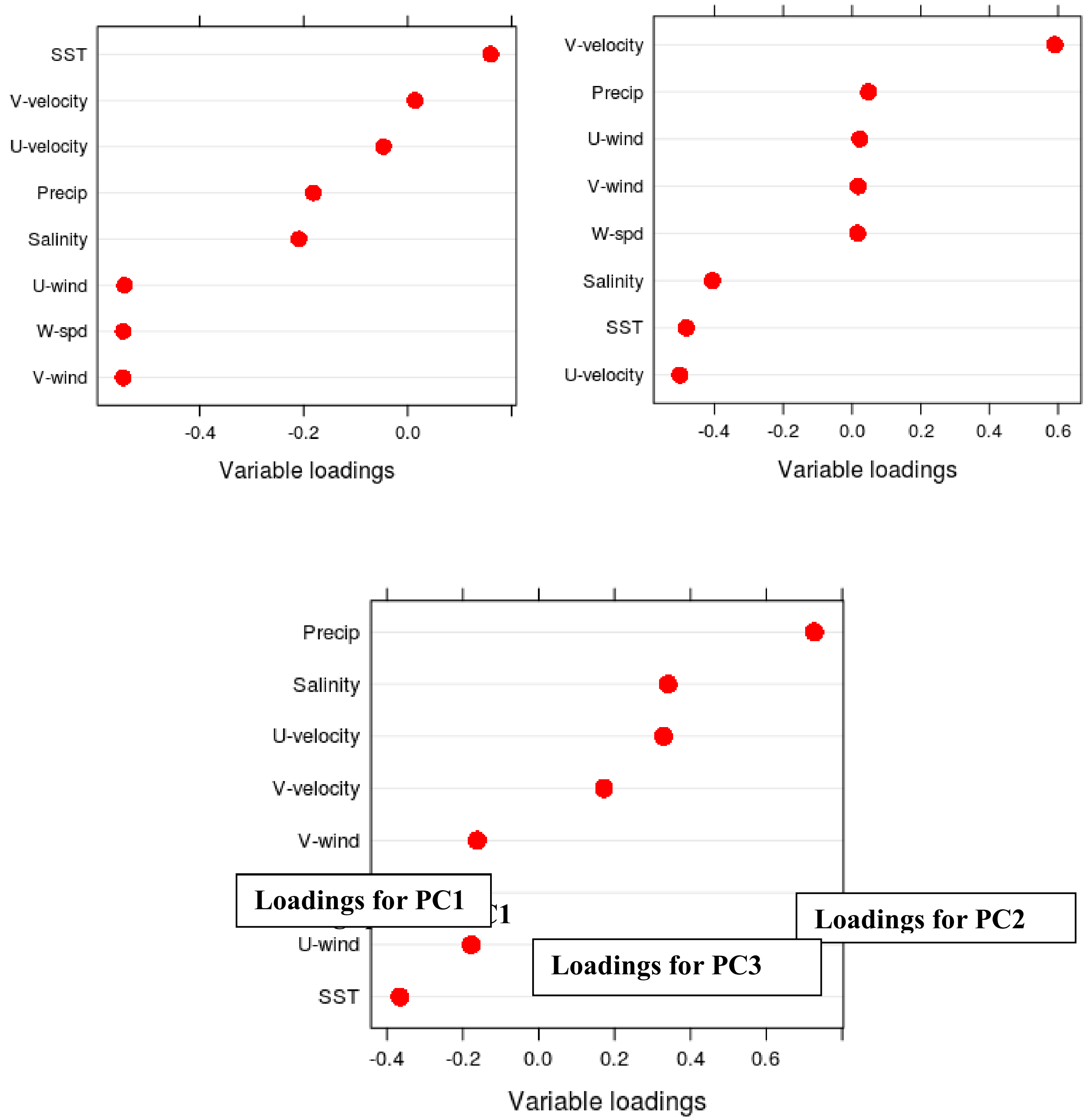

SST
V-velocity
U-velocity
Precip
Salinity
U-wind
W-spd
V-wind
-0.4
-0.2
0.0
Variable loadings
V-velocity
Precip
U-wind
V-wind
W-spd
Salinity
SST
U-velocity
-0.4
-0.2
0.0
0.2
0.4
0.6
Variable loadings
Precip
Salinity
U-velocity
V-velocity
V-wind
U-wind
SST
-0.4
-0.2
0.0
0.2
0.4
0.6
Variable loadings
Loadings for PC1
Loadings for PC2
Loadings for PC3

Figure 10 The pattern of the parameters loadings interfering for each principal components

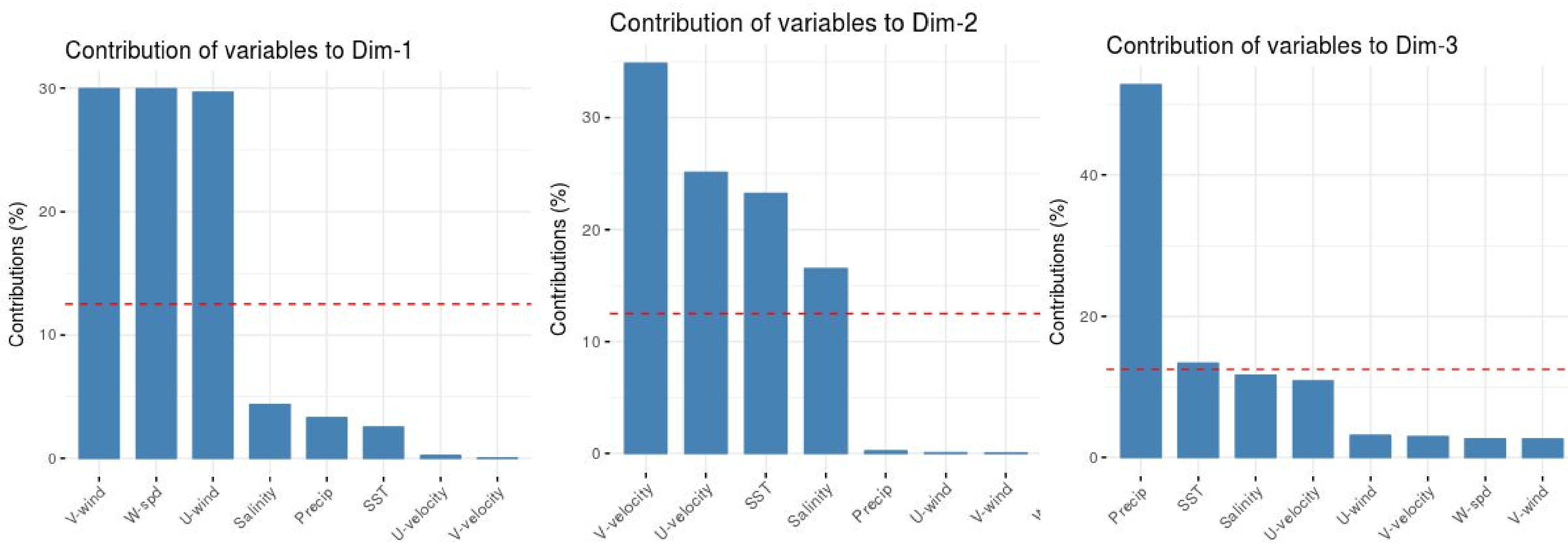


Figure 11 Contribution of each parameters to the three first components.

4.2 Using existing Remote Sensing Data sets to map *Sargassum* Distribution from 2011-2016

This section presents the results for objective 2 of the research. *Sargassum natans* and *Sargassum fluitans* affected several West African countries in the last six (6) years and is likely to continue. There was a common negligence, lack of information and oversight. Using publicly accessible information, we found *Sargassum* recurrence's routine that occurred in West Africa so far and mapped the true scale of the problem. The result is as presented in Figure 4.7 and Table 4.4. As observed in the Figure 4.7 (different locations where *Sargassum* species have been noticed from 2011 to 2016), the recorded *Sargassum*' ground-truth map revealed *Sargassum* presence in West African countries. Also, each author reported a particular period of the species presence along the coasts based on climatic and oceanographic factors which play a role in their migration variability.

This confirmed that since the first unprecedented strandings masses of *Sargassum natans* and *Sargassum fluitans* along the coast West African in 2011, the area has continually experienced its coming, socio-economic and socio-ecological impacts. The result in the Table 4.4 showed the coordinates of the different locations where *Sargassum* species have been signaled over the period of interest. Identification of the locations that have been mostly exposed could help to improve understanding of their dispersal. *Sargassum* species proliferates in core ecological areas and more located on beaches than in the lagoons. Thus, the results revealed that in 2012, the Nigerian media reported the occurrence of *Sargassum natans* and *Sargassum fluitans* massively off the coast of Ondo State. The fishermen in the area observed this between April and July during the wet season (Oyesiku and Egunyomi, 2014). Also, between May 2011 and August 2012, precisely during the rainy season, Solarin *et al*. (2014) observed *Sargassum fluitans* washed ashore on Nigerian beaches. In Togo, throughout the different seasons of the year 2013, Liassou *et al*. (2014) have collected seaweeds essentially macroalgae, classified in accordance with the rules of the systematic classification of plant species. After their investigation, the species photographed, not named by the authors, resembled an expanse of *Sargassum*. Also, in Ghana, during the year 2015, Addico and DeGraft-Johnson (2016) collected *Sargassum natans* and *Sargassum fluitans* offshore and onshore at low tides along the Western coast (on the beaches and in the estuaries); and reported that year was not the first invasion of the algae along the Ghana coast because riverine population declared that first *Sargassum* notification was in 2009.

Furthermore, in Ivory Coast, in May 2016, *Sargassum natans* and *Sargassum fluitans* were observed in the beaches and lagoons. In June 2016, they were observed in the coastal beaches but absent from the lagoons. In July 2016, there was a reduction of *Sargassum* proliferation and the stranded masses of *Sargasum* were covered by sea sand. As advocated by Huckbody (2011) , the beaches of Sierra Leone were invaded by *Sargassum fluitans* towards the end of June 2011 and the great masses in mid August

2011. Another report demonstrated that, in 2014 also, *Sargassum natans* and *Sargassum fluitans* invaded the Sierra Leone's coastal waters in unusually big amounts around June and disappeared around October (EPA, 2015) and appeared during each rainy season (Kamara, 2016). Thus, those informations could allow the public to scrutinise and to complete information on the whereabouts of *Sargassum* presence in their areas. Thereafter, information gaps could be fill to understand the true extent of the problem and move towards a safe future by drawing policy makers' attention to regions that are particularly susceptible to climate impacts for any adaptation assistance.

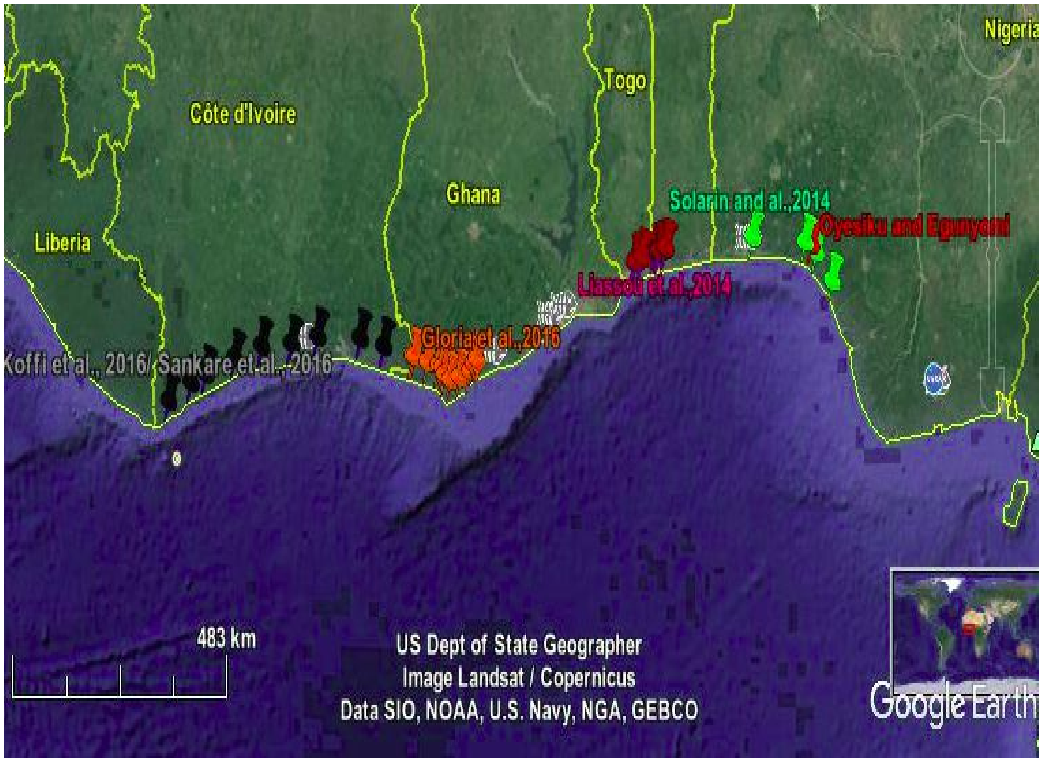


Table 7 **Recent *Sargassum* locations over West Africa**

Countries	*Sargassum* species locations
	Assinie: 5°06'' N, 3°55'' W
Côte d'Ivoire	Grand-Bassam: 5°11'' N, 3°45''W
	Jacqueville: 5°14'' N, 4°25'' W
	Grand-Lahou: 5°08'' N, 5°00'' W
	Fresco: 5°04'' N, 5° 34'' W
	Sassandra: 4°57'' N, 6°04'' W

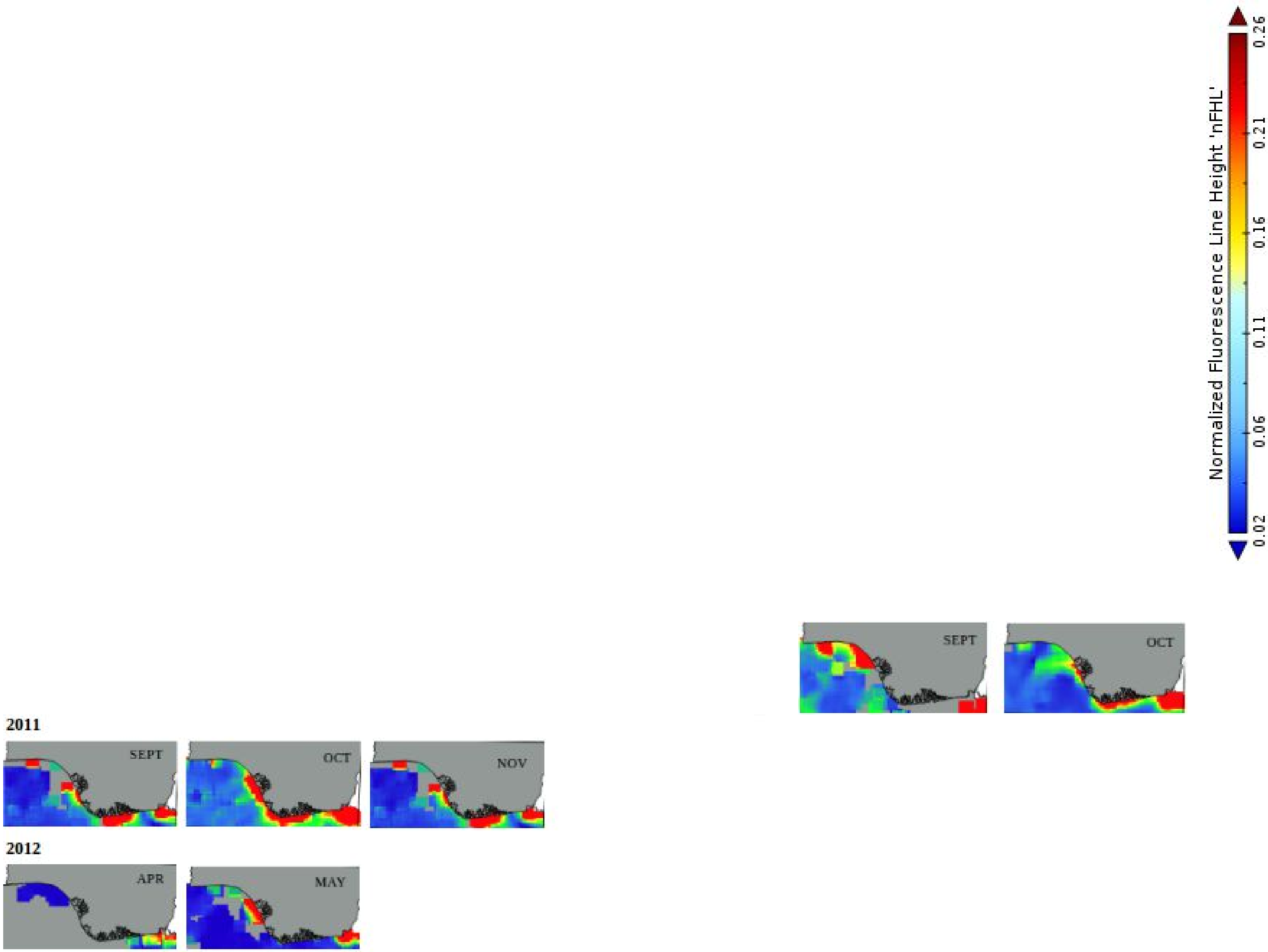
	San Pedro: 4°45'' N, 6°36''W Grand Bereby: 4°39'' N, 6°55'' W Tabou: 4°24'' N, 7°31'' W
Nigeria	Bar beach, Five cowries, Igbosere, Araromi From 6º25'10.47''N, 5º52'9.95''N to 3º25'9.94''E, 4º52'9.95''E Ajegunle-Erun-Ama: 06º 19' 32''N, 04º 30'32''E
Sierra Leone	Lumley Beach 8°29'4"N, 13°14'4"W, Aberdeen 8°30'N, 13°17'W
Ghana	Half-Assini, Egbazo, Assiama, Asunda, Atuabo, Miemia, Axim/Agyan, Essipon, Africa Beach 5°1'44.74"N 2°47'29.51"W 4°58'22.85"N 2°31'20.52"W 4°54'34.38"N 2°17'32.82"W 4°55'59.06"N 2°21'10.06"W 4°50'7.09"N 2°12'22.83"W 4°48'31.39"N 2°10'15.04"W 4°48'21.32"N 1°56'17.62"W 4°52'32.50"N 1°45'58.54"W 4°57'53.44"N 1°41'0.19"W 5°0'49.16"N 1°37'50.30"W

Source: Field data, 2017

The data coverage of Modis nFLH were used to compile image time series of blooms. The set of images in the Figure 4.12 shows the fluorescence of floating algae at 2^0 - 9^0 longitude and 2^0 - 7^0 latitude. Substantial change occurred in the fluorescence over the month, along the Nigerian coast and in the sea surface coverage. The bloom patches were captured by the Modis Aqua nFLH images with high nFLH value as characteristics ~ 0.3 $W \cdot m^{-2} \cdot \mu m^{-1} \cdot sr^{-1}$ as Gower and King (2012) found similar results in the Strait of Georgia in Canada using FLH algorithm to characterize algae blooms from January to March of the year 2009. Moreover, the land and the cloudy ocean areas in the time series are masked as Grey. The result presented in the Figure 4.8 shows that the months entirely cloudy have been removed. The dark blue areas show the lowest surface fluorescence and the red areas, the highest surface fluorescence (see colour scale). It was observed that the monthly fluorescence data peaked in September, October and November in 2011 round the coast. But in 2012, April-May had less expanse of fluorescence. In 2013, the fluorescence in May-November was high compared to April. In 2014, the months of June-September-October recorded a higher-fluorescence than the months of April-November with small fluorescence activity.

Presence of high-fluorescence in 2015 was recorded in May-September-November. However, in 2016, the extent of the fluorescence was quite different in each of the months but it could be noted that in May-June-Oct the bloom fluorescence were located around the coast of Delta, Bayelsa, Rivers and Akwa-ibom States as shown in the majority of the time series images. In April-September-July the fluorescence extended to around the coast of Lagos, Ondo and Ogun States as remarked on certain images. It was discovered that the bloom patterns were more frequent along southeastern coast than southwestern coast. Similar results were found by Gower and King (2012) in Canada, particularly in the Strait of Georgia using FLH algorithm. They observed timing and pattern of plankton blooms spreading in this area with an increase in fluorescence yield in 2009 and 2010. In addition, Frolov *et al*. (2013) with a cross-shore averages of Modis Fluorescent Line Height data showed that seasonal algae blooms off the U.S. West Coast proliferates near-shore from South to North direction. Moreover, respectively Hu and Feng (2016) and Cannizzaro *et al*. (2008) used nFLH and FLH to detect *Karenia brevis* blooms in the colored dissolved organic matters waters and to quantify chlorophyll concentrations associated with *Karenia brevis* blooms in the Gulf of Mexico.

The peak of fluorescence could be due to a great supply in nutrient leading to algae blooms, but its distribution seems not to correspond to the period where *Sargassum* had been seen along the Nigerian coast. Also, the images of the season of *Sargassum natans* and *Sargassum fluitans* abundance most mentioned by the previous authors were not good enough for a possible comparative analysis. In conclusion, we think that maybe the result from the nFHL analysis depicts the blooms of another algae species in the Nigerian water as mentioned by Gower and King (2014) in their study in South Africa where they have defined the bloom patches as a bloom of *Trichodesmium*. Henceforth, The African monsoon, more intense in the south. In Lagos, Benin City and Port-Harcourt, African monsoon goes from March to October, and in the south east (in the wettest area Calabar) from March to November. The rains cease in November in the far south which remains humid due to the influence of the sea (http://www.climatestotravel.com/climate/nigeria accessed on the 27/08/17 at 1:06 mn). That could contribute to maintain the favourable conditions to the recurrence of *Sargassum* species arrival for a long period, as far as it continues to rain. So, more studies have to be done to find out if the blooms patches correspond to *Sargassum* or not.


Normalized Fluorescence Line Height 'nFHL'
0.26
0.21
0.16
0.11
0.06
0.02
SEPT
OCT
2011
SEPT
OCT
NOV
2012
APR
MAY

4.3 Perception of Coastal Residents on the Occurrence of *Sargassum* and their Knowledge about Climate Change

4.3.1 Socio-economic characteristics of respondents

Table 4.5 and Table 4.6 present the socio-economic characteristics of the interviewed households heads, including age, gender, household size, educational level and source of income which influence respondents view point. Out of the 206 respondents, interviewed there were more male headed households than females headed households (See Figure 4.9). Also, the majority of the respondents were aged between 30 and 40 years (33%) which is an indication of their maturity responding to the survey questions. Demographically, Table 4.1 showed also that majority of the respondents (36.4%) had a family size of 4-6 persons, this result implies that each household is likely to get or to share information about climate change from/with their fellow members as presented by Anyoha *et al*. (2013). From Table 4.6, it can be noted that most of the household heads 42.2% acquired primary school education (Figure 4.10) implying that majority of the respondents were not really educated since less than 50% of the population had no access to tertiary education (low literacy level), this may make them more vulnerable and reduce their opportunities to access information apart from the basics ones they got from their immediate environment.

Table 4.5 also revealed that fishing (34.5%), trading (19.9%), farming (10.7%), fish selling (8.3%) were the major occupations of the respondents. Through the fishing and fish selling experience, the respondents were able to show a clearer, concrete comprehension of *Sargassum* occurrence, and on any oceanographic change because they are more familiar to the ocean environment and they are likely to have noticed the hazards linked to *Sargassum* event and to perceive directly the changes which occur over the sea. Their answers were correlated with the ones collected from the other respondents in order to get a general overview. Some respondents had more than one occupation. This according to them is to augment their income.

Table 8 **Respondents major occupations**

Source of household head income	**Frequency**	**Percent (%)**
Beach manager	2	1.0
Civil servant	8	3.9
Contractor	2	1.0
Driving	9	4.4
Farming	22	10.7
Farming, Piggery	3	1.5
Fish selling	17	8.3
Fishing	71	34.5
Fishing, Farming	1	0.5
King of Ete kingdom	1	0.5
Mechanic engineer	1	0.5

Motorbike-man	8	3.9
None	1	0.5
Piggery	1	0.5
Self employed	11	5.3
Student	5	2.4
Taylor	2	1.0
Trading	41	19.9
Total	206	100%

Source: Field data, 2017

Table 9 Summary of the respondents characteristics

Household characteristics (n=206)	Frequency	Percent(%)
Gender		
Male	145	29.6
Female	61	70.4
		100%
Age		
<20	5	2.4
20-30	62	30.1
30-40	68	33
40-50	41	19.9
>50	30	14.6
		100%
Household size		
<4	68	33.0
4-6	75	36.4
7-9	45	21.8
10-12	7	3.4
13-15	5	2.4
16-18	1	0.5
<18	5	2.4

		100%
Education level		
No formal education	26	12.6
Primary school	87	42.2
Secondary school	60	29.1
Tertiary education	33	16.0
Total		100%

Source: Field data, 2017

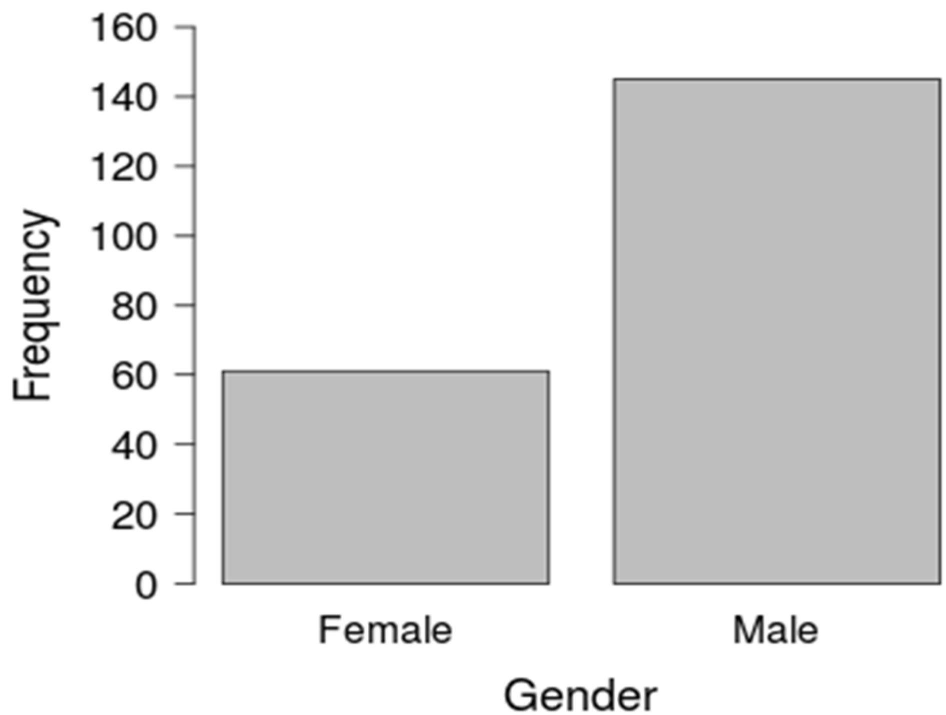


Figure *14* Distribution of respondents' gender according to total in the study

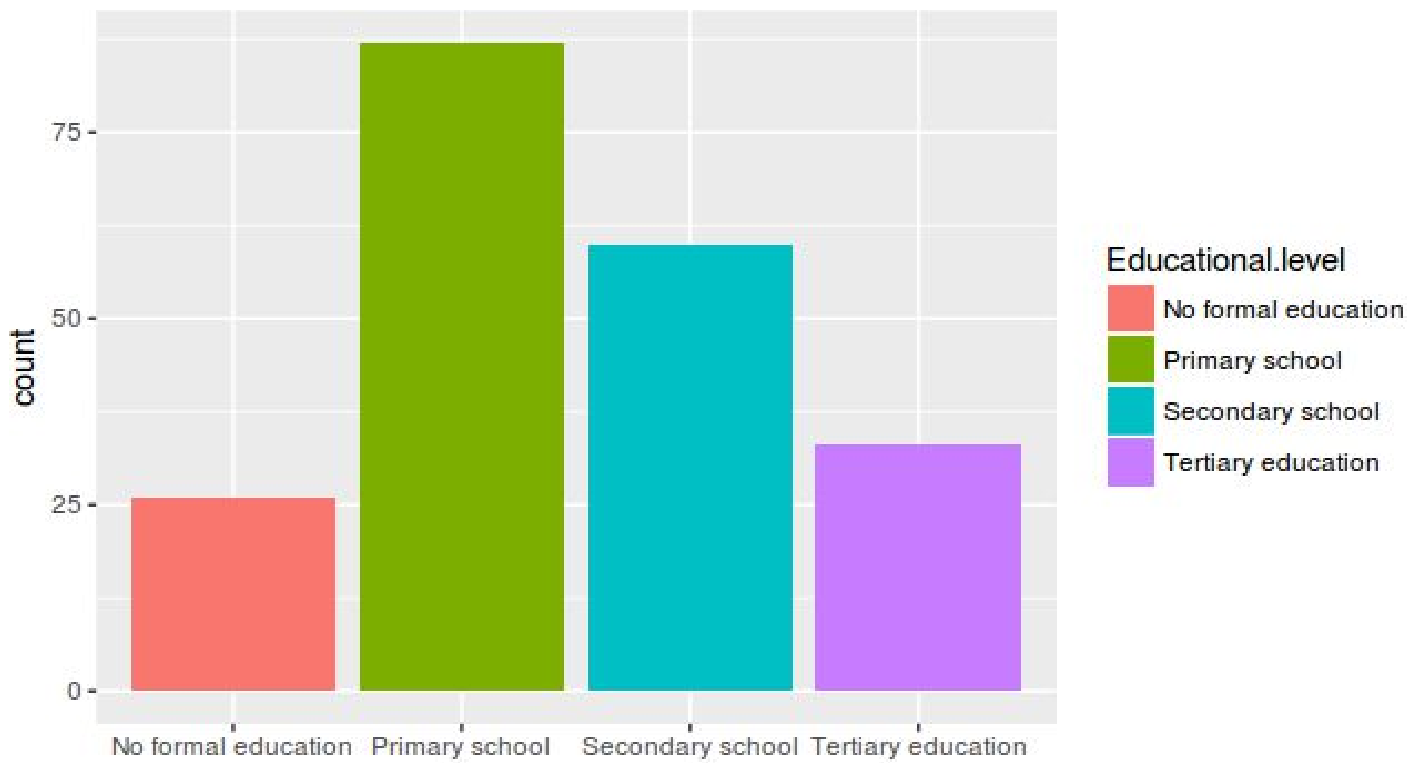


Figure *15* Summary of the respondents educational level according to the total in the study

4.3.2 Communities awareness of climate change

Efforts were made through the administration of questionnaires to the different households in order to ascertain their level of awareness to climate change and their general perception of the topic. The result is as shown in Table 4.7. 69.9% of the respondents were not aware of climate change while 30.1% were aware. In contrast, of this, 92.5% of the respondents in Umuahia South Area of Abia State, Nigeria were aware of climate change, while 7.5% of them were not aware of climate change. That due the fact that the majority 25.8% attended tertiary institution according to (Anyoha *et al*., 2013). Majorly, the fact that the respondents were unaware of the climate change situation could be explained by their low literacy level. About the source where the respondents got information or heard about climate change, the result also showed that 41.7% of the respondents were aware of these changes through personal experiences (what they feel, see, and experience). The respondents (19.9%) who have not heard about the topic did not choose any of the propositions presented by the questionnaire. Their knowledge about climate change, its variability and its repercussions are low and limited.

Apart from them, the other respondents heard about climate change through media (18.9%), at school (1.9%). Some heard about it through several ways such as their own observation, through a visit to a weather station (3.9%), the media and some courses attended in school (1%), the media and a visit in a weather station (1%), then only from media (0.5%), weather station (0.5%) and researchers (0.5%). Moreover, Table 4.7 and Figure 4.11, show that 57.3% of the respondents thought that climate change is principally due to a natural variability. 33.5% affirmed that the real cause of the climate change was the human activities, while 9.2% affirmed that natural variability and human activity were the probable causes of climate change. The majority of respondents affirmed that the main cause of climate change is the natural variability. According to one of the respondent: '*weather change always, it a normal phenomena*'. For them, the changes linked to the climate change are just normal mechanisms which assure the maintenance of the weather cycle. These findings were corroborated with Toan *et al*. (2014) research in Vietnam found. The respondents indicated that climate change is mostly caused by human activities while the other respondents asserted that both natural variability and human activities contribute together to climate change. The awareness about the changing climate was confirmed by climate variability indicators.

Several previous studies on perception and awareness of climate change have pointed out that a greater number of respondents are aware of climate change meaning that they have heard about the topic without enough details or experienced its direct/indirect effects. Even though, they experience it on daily basis, most of those who are aware of climate change are mostly the educated ones with easy access to information through Internet, media and newspapers. Similar study by Ohwo (2015) in Yenagoa, Bayelsa state, Nigeria found that the major sources of people' information about climate change were mainly based on their personal experiences.

Table 10 Households' awareness of climate change

	Frequency	Percent (%)
Awareness about climate change		
No	144	69.9
Yes	62	30.1
Sources of climate change		
Media	39	18.9
Media and School	2	1.0
Media and Weather station	2	1.0
Media and Weather station and Researchers	1	0.5
None	41	19.9
Own observation	86	41.7
Own observation and Media	23	11.2
Own observation and Weather station	8	3.9
School	4	1.9

Cause of climate change		
Both	19	9.2
Human activity	69	33.5
Natural variability	118	57.3

Source: Field data, 2017

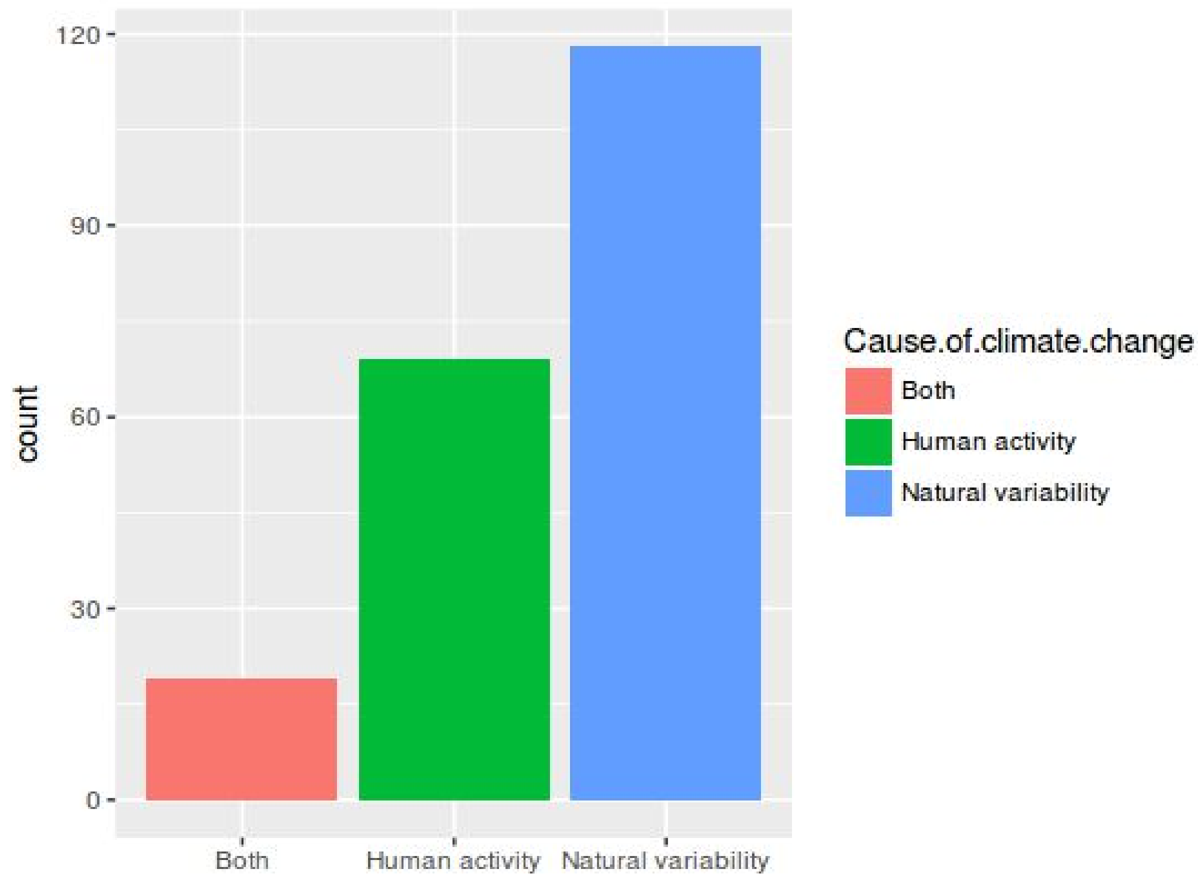
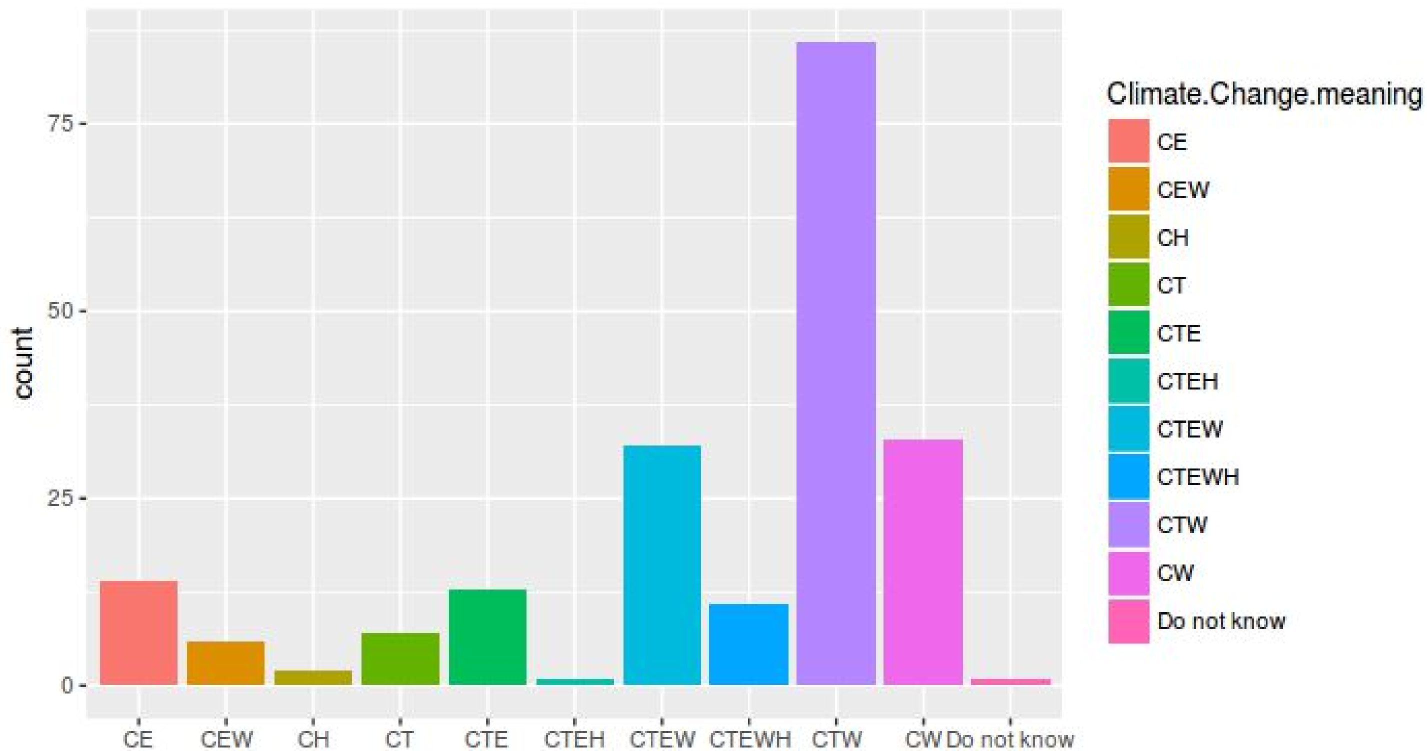


Figure 16 Summary of respondents' answers about the principal cause of climate change according to total in the study

The result of the respondents' understanding of climate change is as shown in Figure 4.12 and Table 4.8. From the result, 41.7% of the total respondents perceived climate change as mainly a Change in Weather conditions and or Temperature (CTW). 16.0% saw it as Change in Weather conditions (CW) while 15.5% believed that climate change is a Change in Weather conditions and Change in Temperature and Change in the Environment (CTEW). Similarly, 6.8% of the respondents perceived climate change as Change in the Environment (CE) and 6.3% were of the opinion that climate change is simply a Change in Temperature and Change in the Environment (CTE). Furthermore, greater percentage of the respondents saw climate change as a "Change in Weather conditions and Change in Temperature (CTW)" followed by "a Change in Weather conditions (CW)".


count
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CTW
CW
Do not know

Table 11 **Households heads responses about the understanding of the 'climate change'**

	Frequency	Percent (%)
Change due to human pollution CH	2	1.0
Change in temperature CT	7	3.4
Change in temperature and Change in the environment CTE	13	6.3
Change in temperature and Change in the environment and Change due to human pollution CTEH	1	0.5
Change in the environment CE	14	6.8
Change in weather conditions CW	33	16.0
Change in weather conditions and Change in the environment CEW	6	2.9
Change in weather conditions and Change in temperature CTW	86	41.7
Change in weather conditions and Change in temperature and Change in the environment CTEW	32	15.5
All proposition CTEWH	11	5.3
Do not know	1	0.5

Source: Field data, 2017

The respondents expressed what they knew about the different proposed impacts of climate change and which of them that mostly affect their community. This is presented in Table 4.9 and Table 4.10. The perceived impacts of climate change as stated by the participants in the sites sampled were: increase in the sea level 48.1%, increase in the appearance of disease 45.1%, increase in the difficulty of navigation 63.1%, recurrence of flooding 69.9%, increase in rainfall intensity 78.2%, increase in the wind speed 80.1% increase in the sea pollution 46.6%, occurrence of rainfall shift 57.8%. The population complained about the occurrence of strong winds recently that destroyed their farms and houses by removing the roofs and making trees to fall on them inducing financial challenges. Respondents added that the strong wind disturbed the boat transport and on some occasions led to accidents. They also observed that the fishermen navigated with difficultly. Also, the respondents complained about the lack of power which makes vain their efforts to tackle constant extreme heat which induces human skin diseases and suffocation. This finding is in agreement with the work of Egbe *et al*. (2014) which reported that strong winds and stormy weather were perceived by the communities and has led to occurrence of many diseases which affected both adults and children who are most vulnerable. The work also reported increment in sea pollution and a shift in the seasonal rainfall which has affected sowing time.

Furthermore, the study of Moniruzzaman, (2013) in Bangladesh also revealed an unusual increment and unpredictability in the rainfall pattern. About 81% of the adult and 61% of the juvenile respondents declared that frequent occurrences of cyclones were affecting more and more their coast. That was also corroborated by Maryam *et al*. (2014) in Pakistan where the respondents were troubled about the negative impact of climate change (76.3%) as a result of flooding and diseases. In the sites sampled the respondents complained about the increase of mosquitoes which has also resulted in malaria prevalence in the area, the recurrence of heat rashes and catarrh due to the sudden temperature variability from hot to cold or vice versa.

Table 4.9 and Figure 4.14 show that 34% of the respondents stated that crop yield has decreased, 30.6% do not know, 26.2% stated constant while 9.2% believe that crop yield has increased. Similarly, 65% of the respondents affirmed that the distance fishermen go to get fish has increased, 17% stated the distance has decreased while 11.2% do not know and 6.8% are of the opinion that the distance has remained constant. Also, the result showed that 70.9% of the respondents believe that the fishing products have decreased, 21.8% believe that the products have increased, 5.8% of the respondents asserted that they have no idea whether the fishing products have increased or decreased while 1.5% stated that the products have remained constant.

Similarly, 46.1% of the respondents stated that the shrimps, crabs products have increased, 43.7% stated that the products have decreased, 6.3% do not know and 3.9% stated that the products have remained constant. Because of over fishing, the fishery activities could have been impacted with a reduction of fish quantities collected by the fishermen, pushing them to go quite far in the sea to get enough products. shrimps and crabs products have increased because it a new sector explored by the coastal population as principal source of income. Before these products were only used for families subsistence. Also, climate change have measurable effect on the quality and quantity of fishery and aquaculture; Climate change will slow down oceanic currents vital for the production cycles in the sea and will affect the migration of fish larvae. in coastal areas, sea level rise may alter the salinity which negatively impact fish population. Thus, Change in fish distribution was a response to environmental changes such as warming water and water acidification, by shifting their latitudinal and depth ranges as reported (Mohammed and Uraguchi, 2013).

The role of climate change on the overall health and population of aquatic species can never be over emphasized. As a result of change in climate, the products of the fishery and the crop yield have decreased and that affects the household heads income and the welfare of their families. Although according to the respondents, the shrimps, crabs products have all increased, the distance covered by the fishermen during fishing has increased as shown in Figure 4.13. Johnson (2012) reported that in Alaska, climate change affects fishermen and fisheries through saltwater intrusion, storm surge, coastal erosion, and other oceanographic events. The atmospheric and ocean temperature variability and the shifts in ocean currents induced a great decrease in the fishes' productivity. The result in Table 4.10 presents respondents' perception about the negative impact of climate change on their communities meaning that if they have ever experienced those proposed impacts. According to the result, 64.9% of the respondents affirmed that their communities were not affected by drought events, 83.5% reported that their community is being affected by coastal erosion, 62.1% affirmed that they were affected by occurrence of new diseases, 56.8% reported be affected by the occurrence of flooding, 62.6% reported that the distance covered by the fishermen is become more and more long in their fish quest, 59.7% reported that the fishermen encountered more difficulty in navigating in the tumultuous waters due to the recurrent strong wind while 37.9% claimed not be affected by occurrence of new diseases, 43.2% claimed not be affected by the occurrence of flooding, 37.4% claimed that fishermen have kept the usual distances they used to do and then 40.3% claimed fishermen were not disturbed by the winds during their activities.

Table 12 Perception of the respondents about the impact of climate change

	Frequency				Percent (%)			
	Const	**Decr**	**DnK**	**Incr**	**Const**	**Decr**	**DnK**	**Incr***
Drought frequency	86	39	52	29	41.7	18.9	25.2	14.1
Sea level	72	18	17	99	35.0	8.7	8.3	48.1
Rainfall intensity	25	14	6	161	12.1	6.8	2.9	78.2
Rainfall shift	42	19	26	119	20.4	9.2	12.6	57.8
Wind speed	26	11	4	165	12.6	5.3	1.9	80.1
Sea pollution	78	10	22	96	37.9	4.9	10.7	46.6
Disease	66	9	38	93	32.0	4.4	18.4	45.1
Flooding	34	19	9	144	16.5	9.2	4.4	69.9
Difficulty of navigation	56	6	14	130	27.2	2.9	6.8	63.1
Coastal erosion	125	19	13	49	60.7	9.2	6.3	23.8

Distance fishers do to get fish	14	35	23	134	6.8	17.0	11.2	65.0
Crop yield	63	70	54	19	30.6	34.0	26.2	9.2
Fishing products	3	146	12	45	1.5	70.9	5.8	21.8
Shrimps, crabs products	8	90	13	95	3.9	43.7	6.3	46.1

*Const: constant, Decr: decrease, Dnk: do not know, Incr: increase. Field data, 2017

Table 13 Perception of the respondents on the negative climate change impact on their communities

	Frequency		Percent (%)	
	No	Yes	No	Yes
Drought frequency	143	63	69.4	30.6
New diseases	78	128	37.9	62.1
Flooding occurrence	89	117	43.2	56.8
Distance length fishermen have to do	77	129	37.4	62.6
Difficulty of navigation due to wind	83	123	40.3	59.7
Coastal erosion occurrence	12	34	83.5	16.5

Source: Field data, 2017

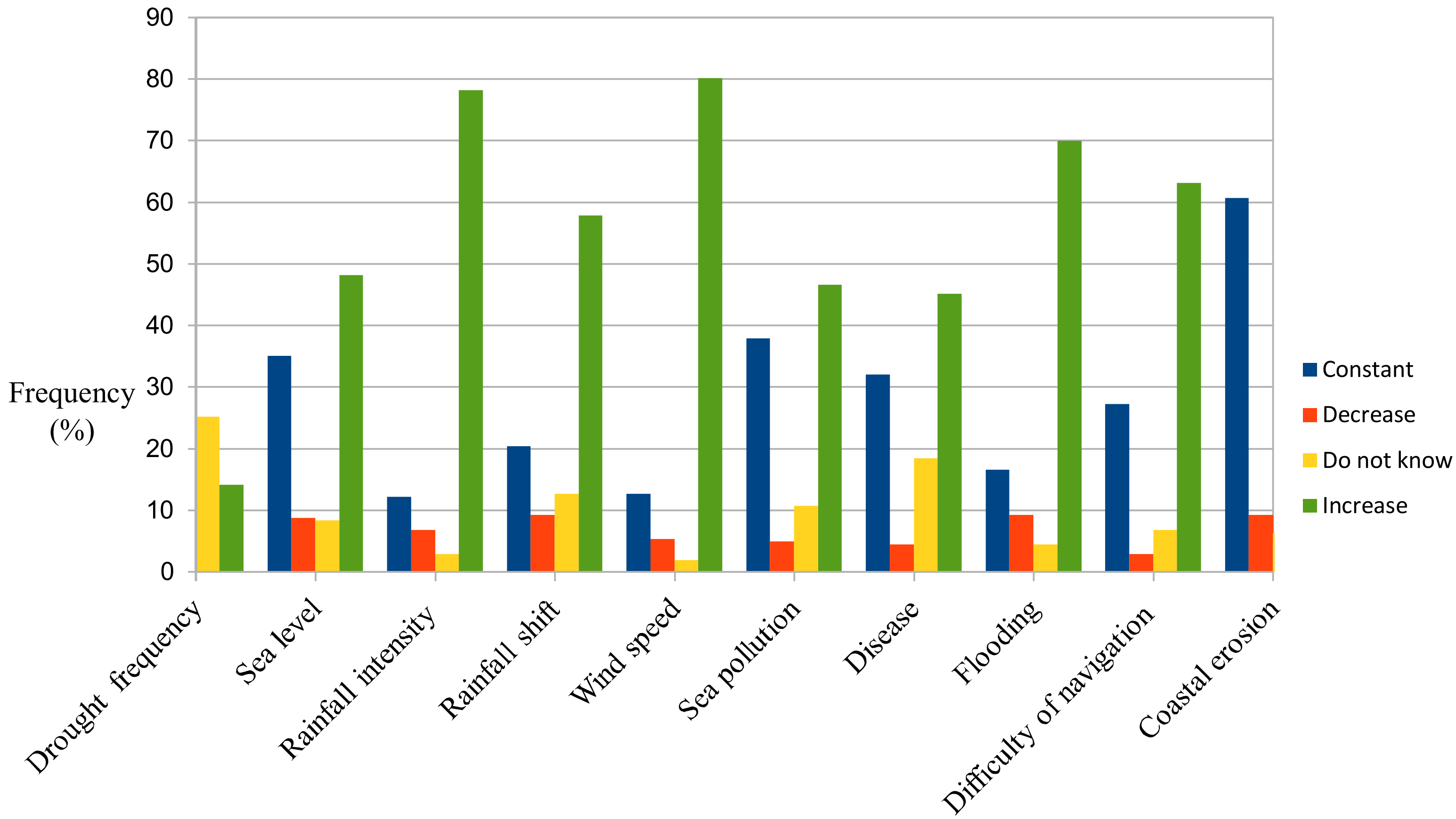


Figure 18 Perceived variability of the climate change impacts

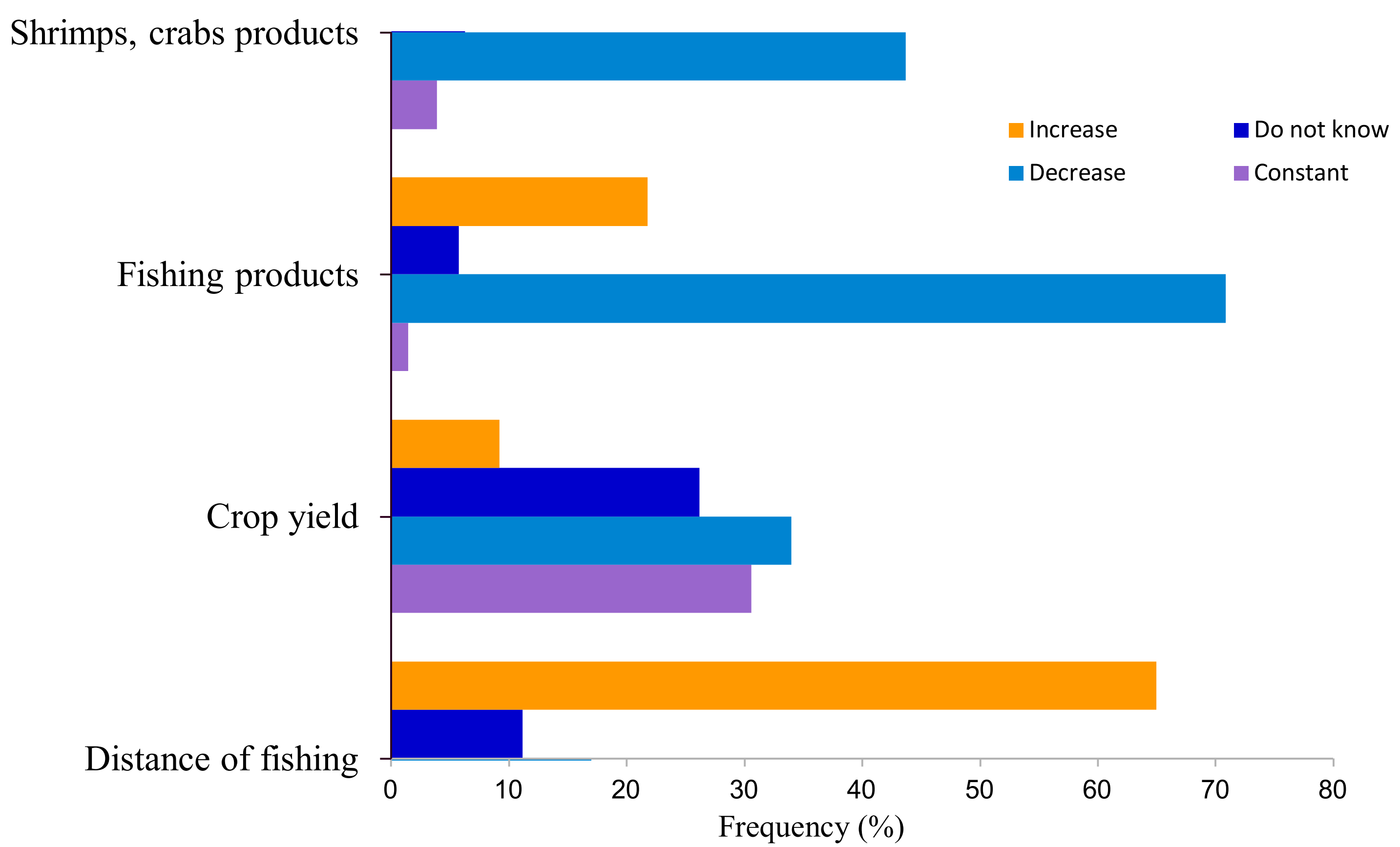


Figure 19 Respondents' view on fishers and farmers products

4.3.3 Perception of the people on *Sargassum* occurrence

The Table 4.11 presents that, 71.4% of the respondents noted the occurrence of the algae in their area, while 14.6% did not notice it and 14.1% do not know anything about the presence of *Sargassum* species in their areas. Furthermore, 39.8% of respondents affirmed that *Sargassum* species occurrence is not linked to climate change but more linked to the level of sea pollution while 32.5% agreed that *Sargassum* species occurrence is linked to climate change and 27.7% of the respondents have any idea of the reasons under the presence of the algae species in the area.

The respondents reported that they have not noticed the presence of *Sargassum* species in their streams. This observation was made of their water body at Egan oromi and Igboja (Lagos State). This is in contrast with the finding of Sankare *et al*. (2016) which reported presence of *Sargassum* species in the marginal-coastal environments (lagoons, rivers). However, at Egan oromi, Snake island and Igboja (Lagos State), the respondents revealed the presence of another weed specie identified as being *Eichhornia crassipes*, which disturbs the movement of boat, the spreading of the nests and make the rivers and surroundings dirty. *Eichhornia crassipes* invades the water surface and dries up and within five (5) hours the water changes of state and becomes salty. The presence of this specie shows the degree to which the water body is polluted (See Appendix B). Its presence was also observed on the Araromi shore, together with the *Sargassum* species, helped by the waves motions.

Table 14 Respondents perception about *Sargassum* occurrence

	Frequency			Percent (%)		
	Do not know	No	Yes	Do not know	No	Yes
Noticing of the occurrence of algae	29	30	147	14.1	14.6	71.4
Link of algae presence and climate change	57	82	67	27.7	39.8	32.5

	Frequency	Percent (%)
Period of *Sargassum* upcoming		
5-10 years	52	25.2
Do not know	60	29.1
Less than 5 years	76	36.9
More than 10 years	18	8.7
Season of abundance		
Both	58	28.2
Do not know	60	29.1
Dry season	11	5.3
Rainy season	77	37.4

***Sargassum* effect on people's activities**		
Disturb fishing	46	22.3
Disturb fishing and Disturb boats transport	34	16.5
Disturb fishing and Disturb boats transport and Odor	2	1.0
Disturb fishing and Odor	3	1.5
Do not Know	57	27.7
None	64	31.1

Source: Field data, 2017

The result in the Table 4.11 shows that 36.9% of the respondents declared that they have noted the presence of *Sargassum* species over a period less than five (5) years, 29.1% of them did not know how long the species have been in the area and 25.2% of respondents affirmed that *Sargassum* species occurred since five (5) to ten (10) years. This concurs with what Fardin *et al*. (2015) have reported, since 2011 Caribbean islands and West African countries shores have been inundated by a mass of *Sargassum*. That could be explained by all those disturbances in the ocean environment such as increase in sea temperature, changes in global water cycle, changes in salinity which affect sea currents and marine life, wind also affects currents which influence the transport and distribution of floating seaweeds according to Komatsu *et al*. (2014). These oceanic parameters are linked in such a way that any disturbance to one induces immediate imbalance in the others.

Then, Table 4.1 shows that only 8.7% of the respondents argued that *Sargassum* species occurred since more than ten (10) years that has been corroborated by Webster and Linton, (2013) findings in Texas who reported that the most recent period of heavy *Sargassum* landings have occurred between 1999 and 2007 on Galveston's beaches. Furthermore, most of the respondents (37.4%) said that *Sargassum* occurred mostly during rainy season as reported in Côte d'Ivoire by Sankare *et al*. (2016) who explained that *Sargassum* species invaded coastal marine waters, beaches and lagoons around April-May-June, then began to die during the tornado season and disappeared completely during major rainy seasons May to July, where winds are strong, thereafter during June-July rains, the algae disappeared totally from the waters. Also, Solarin *et al*. 2014 emphasized on the aforementioned by reporting *Sargassum* species occurred principally during the rainy season (May-August) in the south-western region of the coast Nigerian. 29.1% of the respondents did not know what was the season of abundance of *Sargassum* species, 28.2% of the respondents affirmed that *Sargassum* occurred in abundance during both seasons (dry and rainy seasons) while 5.3% said, during dry season. For the period of the field survey, we observed the presence of *Sargassum* at Lagos State, precisely on the sea, the shores and the beaches. The species identified corresponded to *Sargassum fluitans* characterized by floats without spines according to the description by Schell *et al*. (2015); Koffi *et al*. (2016); Addico and DeGraft-Johnson (2016) (See Plates I, II).

Plate II *Sargassum fluitans* Lagos State - Eleko

Plate I *Sargassum fluitans* Lagos State - Lekki

Source: Field data, 2017

Table 15 Locations coordinates of the observed *Sargassum fluitans*

Local Government Areas	Beaches	Coordinates GPS
Ojo	Abese beach	N06^{0}25’21.3’’ / 06^{0}25’19.9’’ E003^{0}26’31.8’’/003^{0}26’32.5’’
	Olomenta beach	N06^{0}24’01.9’’ / 06^{0}24’01.6’’ E003^{0}06’27.3’’ / 003^{0}06’14.2’’
	Igboja kekere beach	N06^{0}24’01.6’’ / 06^{0}24’01.9’’ E003^{0}06’07.0’’ / 003^{0}05’56.9’’
Eti-osa	Private beach-victoria island	N 06^{0}26’59.09’’ /06^{0}26’59.99’’ E 003^{0}23’58.02’’ /003^{0}23’59.99’’
Ibeju-lekki	Eleko beach	N06^{0}26’18.2’’ / 06^{0}26’19.8’’ E003^{0}51’08.2’’ / 003^{0}51’18.2’’
Ilaje	Araromi	N06^{0}19’23.6’’ / 06^{0}19’55.5’’ E004^{0}29’15.9’’ / 004^{0}29’36.7’’

Source: Field data, 2017

The species were observed at several locations along the western Nigerian coast on the 16th May 2017, the 10th and 12th June 2017 (Plates I, II and Table 4.12). Knowing that according to Redmond *et al*. (2014), that *Sargassum fluitans* is more sensitive than *Sargassum natans* meaning that any temperature disturbance which bring the sea surface temperature inferior or superior to 24 - 30^{0} C could affect the growth and lifetime of *Sargassum fluitans*. Thus, the presence of only *Sargassum fluitans* could be due to the fact that when the observation was made the second species was not yet released by the water, or probably because of the conditions that led to *Sargassum natans* development and growth were not present at the time. Moreover, each of the waves discharged the species and as a result they covered the shores where they were amassed in *Sargassum*' clod. Those which have not been piled up were coated by the sea sand. When the decomposition starts, it attracts insects and releases a nauseous odour. According to the respondents, *Sargassum* presence disturbs fishing, disturbs nests as found in Nigeria by Solarin *et al*. (2014) who reported that fishing gear and nests have been clogged by the floating mass of *Sargassum*. This results in *Sargassum* cling on the fishing nets thereby making preparations for fishing trips more time wasting. Furthermore, according to the respondents, *Sargassum* species disturbs boat transport and makes sea and beaches dirty. Quite a negligible number of respondents talked about odour due to the decomposition and the presence of insects. Some fishermen affirmed that the fishes run away when they feel the presence of *Sargassum* which makes difficult their activity. Sometimes, the fishermen nests catch mass of *Sargassum*, when they realised that the *Sargassum* rafts trapped fishes sometimes already dead, they are not disturbed, instead the fishers spent time to sort the contents of the nets. Thus, according to the household heads (Table 4.13) the most affected people by these species invasion are the fishermen, fish sellers, and coastal population as demonstrated by Hinds *et al*. (2016) and Solarin *et al*. (2014) who noted that the fishermen reported a low fish productivity and also the fishermen designed the shores, sea, and beaches as the areas most affected.

Table 16 **Persons and area more affected by *Sargassum*'s presence**

	Frequency	**Percent (%)**
Beaches and Fishermen	8	3.9
Beaches and Fishermen and Coastal population	2	1.0
Beaches and Fishermen and Fish sellers	9	4.4
Beaches and Fishermen and Fish sellers and Coastal population	11	5.3
Coastal population and areas and Fishermen	4	1.9
Coastal population and areas and Fishermen and Fish sellers	3	1.5
Do not know	62	30.1
Fishermen	42	20.4
Fishermen and Fish sellers	4	1.9
Fishermen and Fish sellers and Coastal population	2	1.0
Fishermen and Sea and Shores and Beaches	28	13.6
Fishermen and Shores and Beaches	18	8.7

Fishermen and Shores and Beaches and Fish sellers	5	2.4
Fishermen and Shores and Beaches and Fish sellers and Coastal population	7	3.4
Beaches	1	0.5

Source: Field data, 2017

4.3.4 Consequences of climate change and *Sargassum* species occurrence on livelihood

The results of the consequences of climate change and *Sargassum* species occurrence on livelihood are presented in Table 4.14. The result indicated that majority of the respondents 77.7% affirmed that climate change affected their activities while 22.3% asserted the contrary. 75.2% of the respondents said that their income are affected while 24.8% said their income were not affected by climate change. Furthermore, 66.5% of the respondents as against 33.5% of the respondents declared that their feeding have been affected. Also, 59.7% of the respondents noted that the change in climate impacted their welfare then 64.1% of the respondents as against 35.9% affirmed that their health has been affected. The majority of the respondents acknowledged that they have been affected by the effects of the climate change. In a similar study, Ohiole *et al*. (2016) found that 62.5% out of the total number of respondents interviewed agreed that the consequences of the climate change were becoming harsh in Nigeria and causing famine, socioeconomic difficulties, occurrence of diseases, rise in environmental problems and decline of natural resources in coastal communities in Nigeria.

Also, Berhe *et al*. (2017) reported that in Ethiopia, the communities were impacted by the climate change, principally their incomes as a function of their occupations. Similar study in UK coast by Zsamboky *et al*. (2011) suggested that climate change affects coastal communities' health due to flooding and heatwaves. The results in Table 4.14 indicated that majority of the respondents claimed that they are not affected by the occurrence of *Sargassum* species. Only 37.9 % of them responded that their activities have been affected, 32% reported that their incomes have been affected, 39.3% responded that their feeding have been affected, 2.4% their welfare and 1.5% their health have been impacted by the presence of *Sargassum fluitans.* As reported by Zsamboky *et al*. (2011) and UNEP *et al*. (2016) in Caribbean, massive influx of *Sargassum* disturbs coastal marine life (dead fish), impact socioeconomic livelihood (activities) of the coastal household. The population of this seaweed affects the quantity of fishes normally caught which could be reverberated on the households whose feeding is principally based on fisheries products.

Therefore, *Sargassum* events could become a worrying problem for the areas where aquaculture plays important role in food production. Similarly, Fardin *et al*. (2015) and

Solarin *et al*. (2014) work have shown that the recent influxes of *Sargassum* in Caribbean and Nigeria affect the operations of fishing, the fishermen' health and disrupted coastal fishing communities. Also, the beaches in Lagos State (areas of tourism and recreation) may be affected by the accumulation of *Sargassum* species which make the places dirty and not attractive. As argued by Franks *et al*. (2011) tourism was impacted by the continual intrusions of *Sargassum* into beaches followed by decomposition and the releasing of associated odors. *Sargassum natans* is toxic when it releases the poisonous hydrogen sulphide in great quantity. That has also been pointed out by UNEP *et al*. (2016). The hydrogen sulphide can induce fish mortality but it does not directly affect human health in the study areas. From the questions asked 'do you have adaptation measures to climate change? And 'do you have adaptation measures to algae species occurrence? Yes, no', the majority of the household heads 87.4% responded that they do not have adaptation measures against climate change while 12.6% answered yes they have. Some of them strove against the heat by planting trees in their compound. Others turned on their generator to refresh the air. 84.5% of the respondents affirmed do not have adaptation measures against the presence of *Sargassum* while 15.5% answered yes they have by removing the algae from the nests or tried to take off the algae at the water surface (See Table 4.15).

Table 17 Impact of climate change on communities livelihood

	Frequency		Percent (%)	
	No	**Yes**	**No**	**Yes**
Impact of climate change on				
Activity	46	160	22.3	77.7
Income	51	155	24.8	75.2
Feeding	69	137	33.5	66.5
Welfare	83	123	40.3	59.7
Health	74	132	35.9	64.1
Impact of *Sargassum*				
Activity	128	78	62.1	37.9
Income	140	66	68.0	32.0
Feeding	125	81	60.7	39.3
Welfare	201	5	97.6	2.4
Health	203	3	98.5	1.5

Source: Field data, 2017

Table 18 Respondents adaptation measures

	Measures about climate change		Measures about *Sargassum*	
	Frequency	**Percent (%)**	**Frequency**	**Percent 9%)**

No	180	87.4	174	84.5
Yes	26	12.6	32	15.5

Source: Field data, 2017

In conclusion, the quantitative analysis corroborated with qualitative analysis demonstrates the relationship between climate change, the occurrence of *Sargassum natans* and the vulnerability of the population and that have been shown through a qualitative network analysis using codes and codes categories. The most commonly repeated themes in the ensemble of the interviews administered over the sampled locations were presented in Figure 4.15. This figure showed the relationship between each of the reported themes, meaning connection between the elements of the network: the codes and codes categories representing the different perceptions of the respondents. Seven codes categories and forty-seven codes have been designed. Each code categories constituted the center of relation of the network and the codes around established specific relation with them. For instance, for the reader to comprehend how the social network have been interpreted, let take an example of the code category 'cause climate change' is in relation with the following codes 'natural variability, human activity, natural variability and human activity'. That means respondents have related the cause of the change to these three attributes. Thus, these attributes were highlighted as potential causes of climate change for each of the codes categories (See Appendix C).

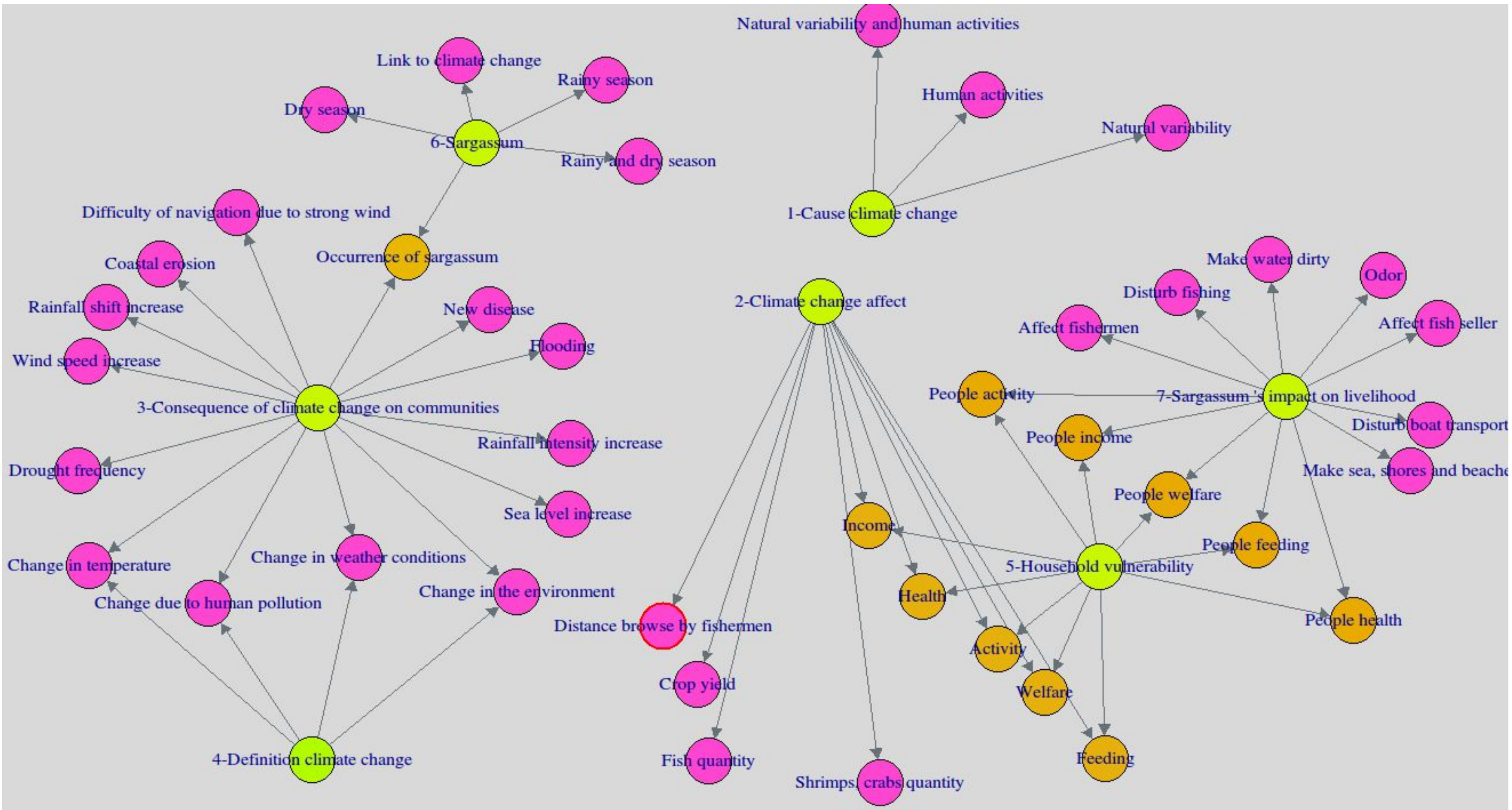
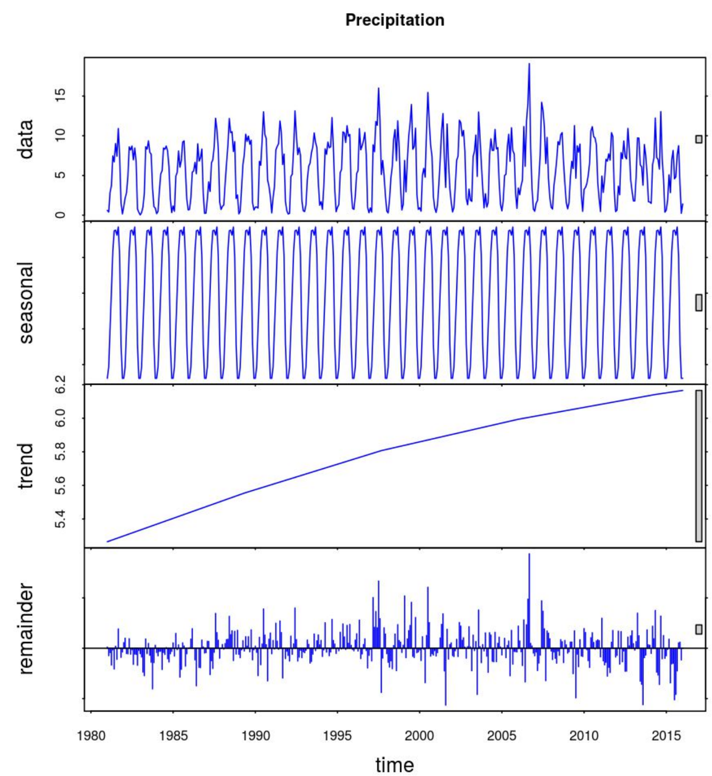


Figure *20* Relationship between respondents' perceptions

4.4 Examination of the Past Trend of the Major Variables that drive *Sargassum* Phenomena along the Nigerian Shores.

This section discusses the results for objective 4 of the research. The test of seasonality (data deseasonalisation) in Figure 4.16 to Figure 4.19 showed that it exist a seasonality in the data. This implied that the values of the variables reach maxima / minima and are repeating themselves periodically with the same behavior. Also, the remainder of the elements represent the errors designed as the differences between the observed and expected values which could be due to external factors contributing to the implementation of each oceanic variables. The trend line of the precipitation, sea surface salinity, sea surface temperature, v-velocity presented in the Figures shows increasing patterns and the trend line of the wind speed, u-velocity, u-wind shows a decreasing in the patterns. In addition, the trend line of V-wind shows an increasing of the trend around the year 2007 followed by a decreasing of the trend from there to around the year 2014 and decreases again.

Secondly, the test of autocorrelation using the acf and pacf function on the variables (See Figure 4.20 to Figure 4.23) identifies the presence of autoregression (AR) and moving average (MA) components in the residuals, verifies if the oceanic variables are correlated or not and detects the repetitive variables patterns over time. In each acf plot, the autocorrelation at lag 0 (event occurring at time t + k with k the lag extent) for all the variables, which exceeded the significance bounds have been removed. Most of the remaining lags (spikes) in the acf and pacf plots were outside the blue dotted horizontal lines (significance area) meaning that the variables are autocorrelated in contrast with the null hypothesis for the acf which is that the time series observations must not be correlated to one another. As a result from that, the information available in residuals can be extracted by AR and MA models thus the seasonal component contained in the residuals has been detected at different lag levels time. Using the lags, the autocorrelation function have been estimated. Furthermore, acf and pacf plots visualization presents the number of autocorrelation lags equals to 42 for each variables which describes significant deviations from zero correlation at different lag points close to each other. That suggests that there is seasonalilty in the data patterns which are spaced by some months, in accordance with the result obtained after the deseasonalisation of the data.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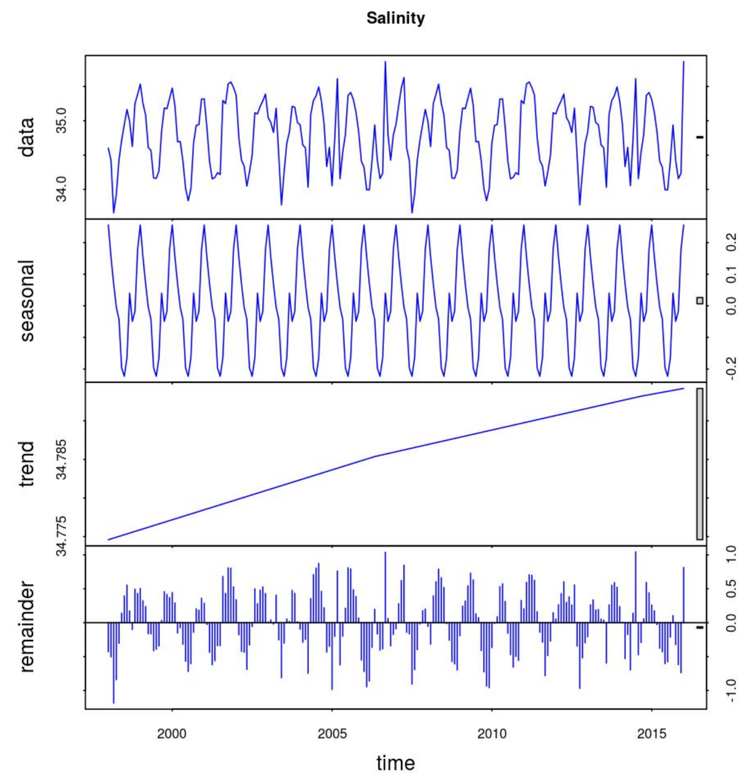
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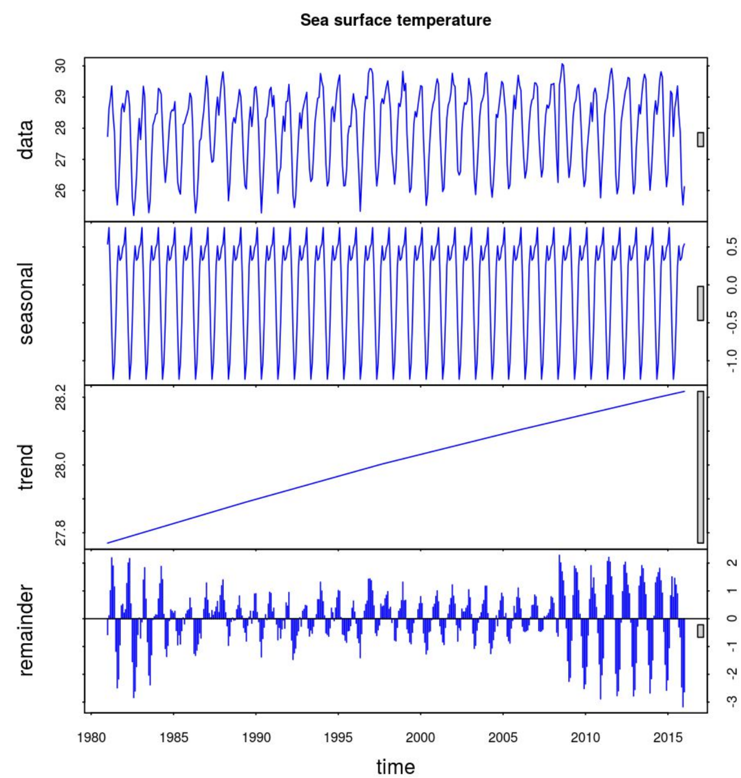
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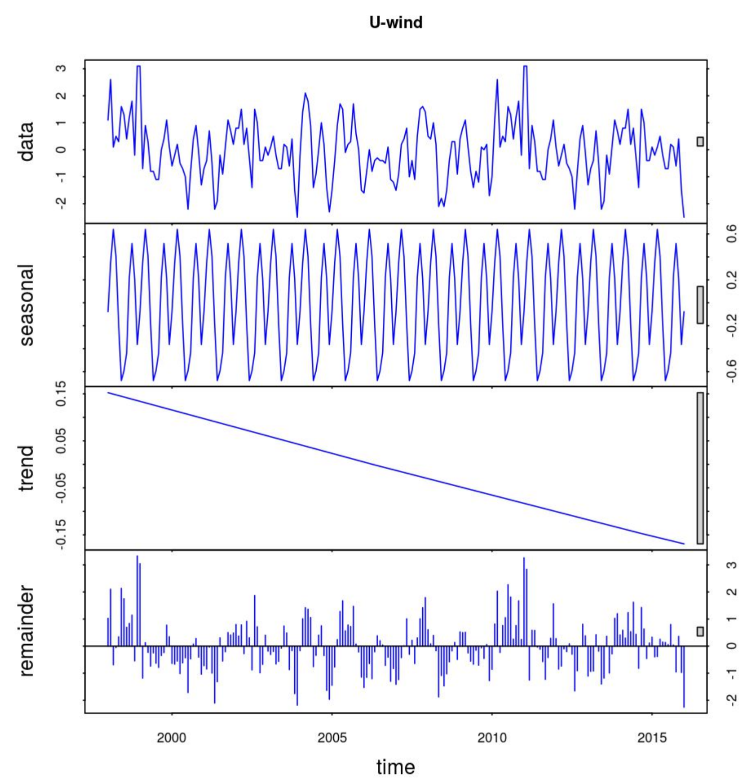
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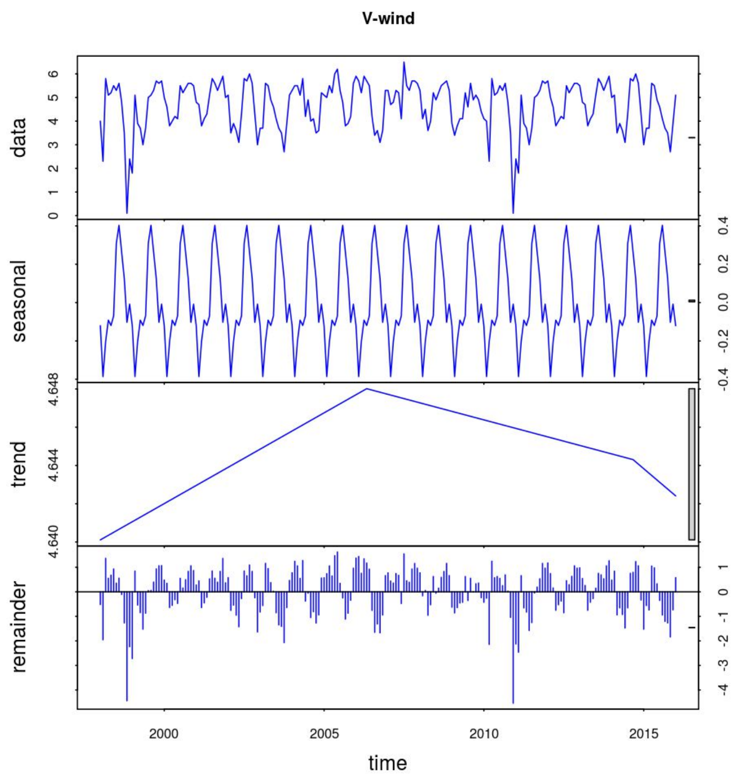
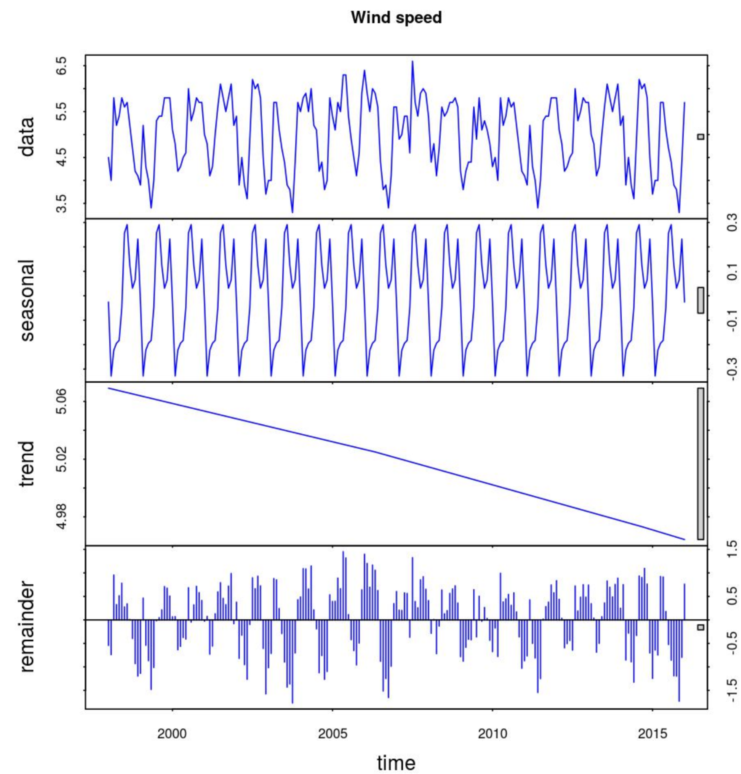
2010
2015


V-wind
data
seasonal
trend
remainder
time
2000
2005
2010
2015


Wind speed
data
seasonal
trend
remainder
time
2000
2005
2010
2015

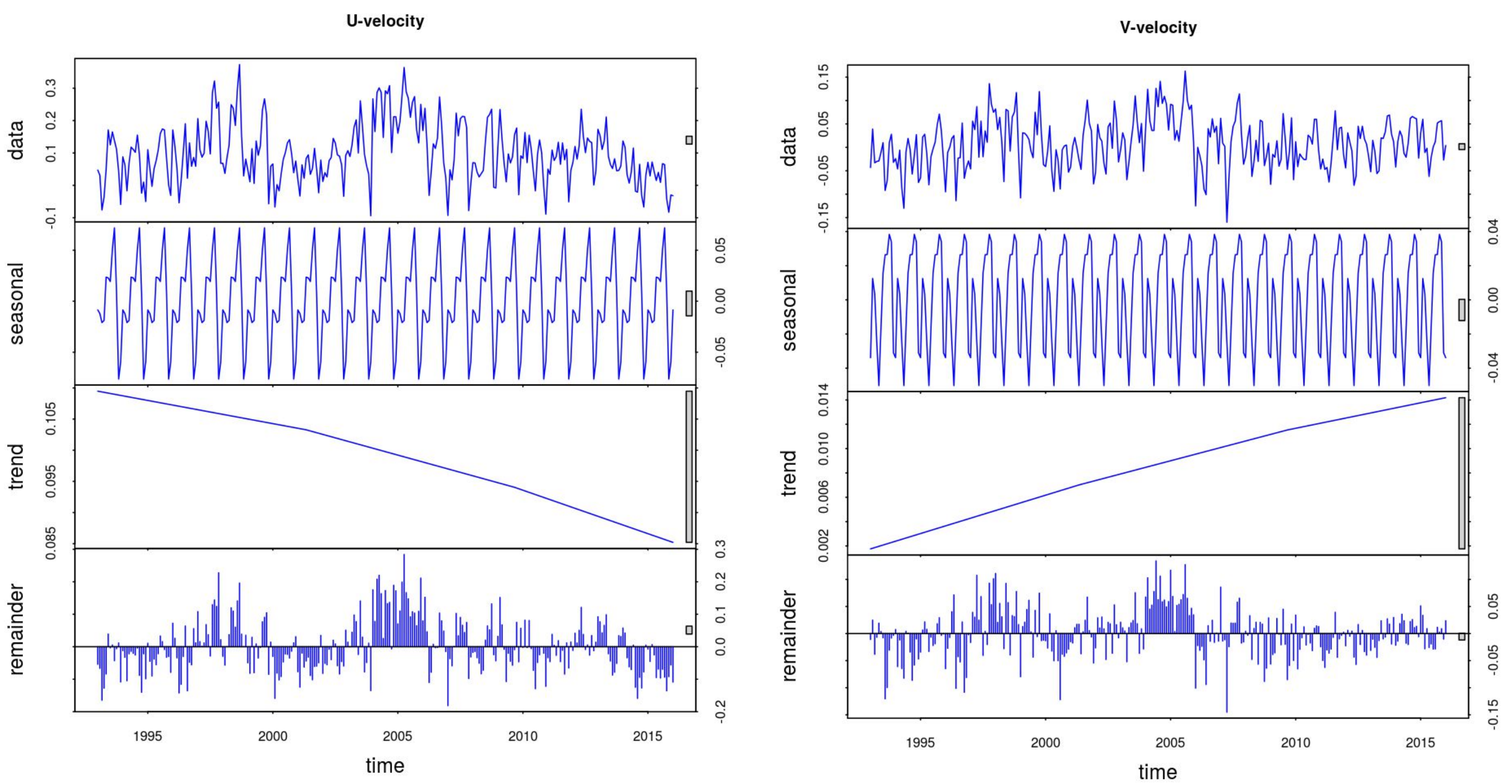
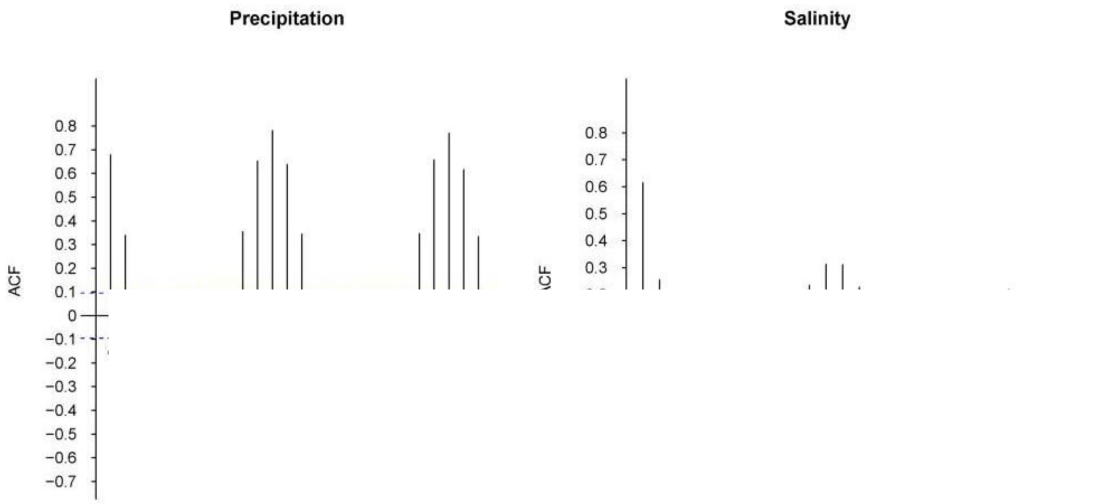
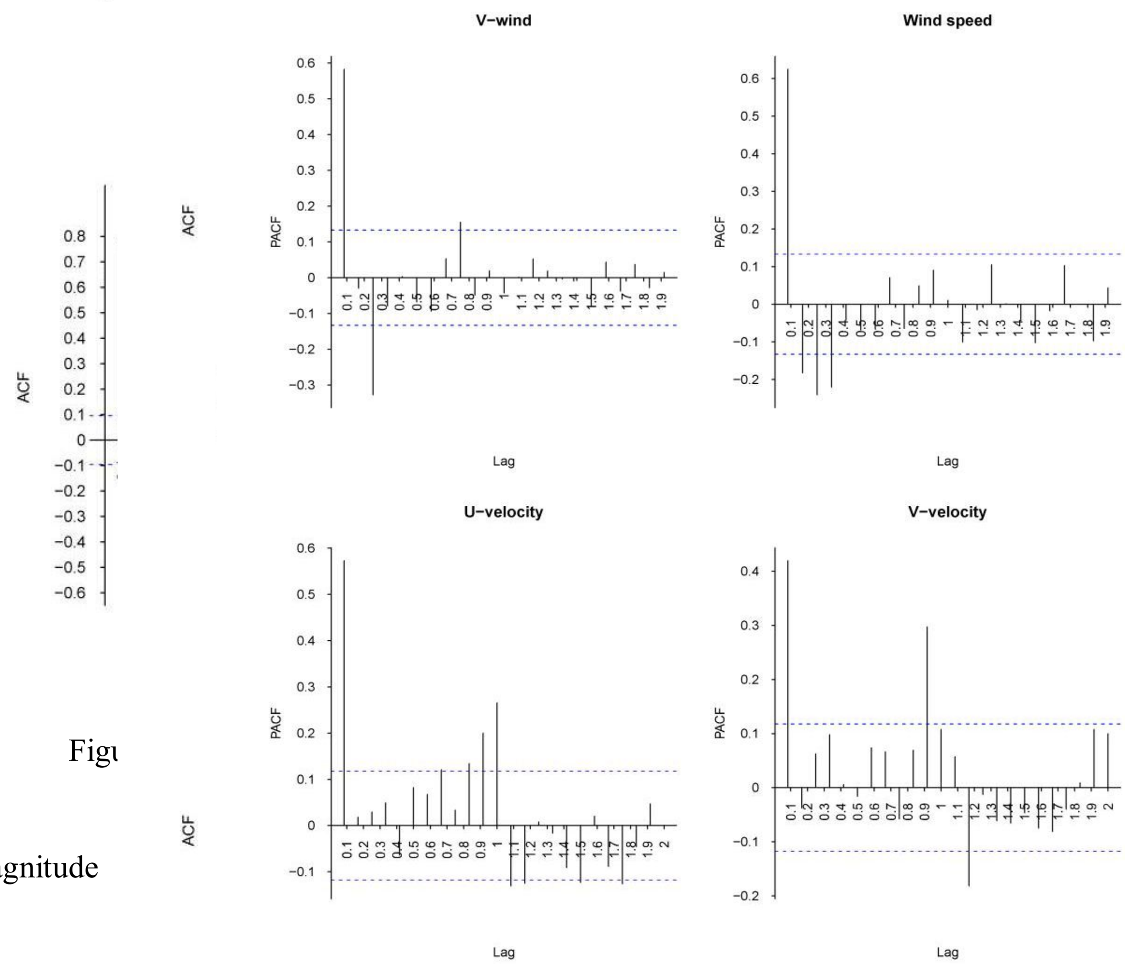


Figure *24* Seasonal times series decomposition on coastal u and v velocity component data by Loess method





Figu

magnitude

Figure 28 Serial autocorrelation estimation by pacf function for the second set of oceanic data

of oceanic data

slope after removing the white noises from the data, also shows the value of variables autocorrelation, th

tau, the p-value test and the bounds limits. The Prewhitening method prevented the false detection of

revealed that each displayed trends measured inter and intra-annual variations which occur over ti

negative tendency. Furthermore, the result shows that there is a positive trend for precipitation greater

for salinity, u-v velocity, v-wind, wind speed less than 1. Also, there is a negative trend for the sea surf

Moreover, the precipitation, the sea surface salinity, the u-velocity, the v-velocity, the v-wind and the w

Sen's slope value meaning an increasing linear trend with a positive Kendall tau suggesting that b

observed data increase together. Compared to the aforementioned seasonal variables' decomposition re

trend has been modified giving the real trend contained in the data. Time series of precipitation, salinit

velocity component show the trend kept the direction pattern. Time series of u-velocity component and

negative to positive direction, describing an increasing trend, while the sea surface temperature change

direction, describing a decreasing trend.

This implies that when climate change affects the rainfall patterns, it drives to intense floods and s

nutrient from the land through runoff processes furthering to more *Sargassum natans* and *Sargassu*

changes in precipitation will lead to a certain changes in the sea salinity which is materialized by increa

the variation of the West Africa monsoon during boreal summer causes important disturbances at

circulation which impact directly sea surface temperature, precipitation and wind patterns. The warm s

Gulf of guinea would lead to intense rains near the coast. Furthermore, the currents and the winds

associated with coastal upwelling process participating to *Sargassum* distribution shift along the Nig

2013). Moreover, sea surface temperature and u-wind have a negative Sen's slope value meaning a decr negative Kendall tau suggesting that both of the trend and the observed data decrease together.

The Sig column shows that all the variables have a Kendall P-value greater than 0.05 indicating statistically significant. This result does not suggest that there is no trend, instead that the variables pr which is built slowly over time. Similarly, Ta *et al*. (2016) in their study across West Africa region, fou non-significant rainfall trend. Also, in the Atlantic cold tongue, they demonstrated a significant inc temperature (SST1) trend which was linked to an anomalous deceleration of the wind at 700 hPa level, and the warming of the oceanic area is related to extreme rainfall events and the latitudinal evolution o Convergence Zone) in the eastern part of West Africa including the south of Nigeria. Also, the maturity Oscillation (ENSO) is associated with an insignificant trend in the zonal SST gradient during the b events across the equatorial Pacific Ocean (L'Heureux *et al*., 2013).

Several works such as IPCC (2007), IPCC (2014) and EPA (2016) have found that there had been i patterns conducting to a derangement in the ocean parameters behaviour. Thus, the Nigerian coastal increasing spatio-temporal sea surface temperature (SST), that could be due to the greenhouse gas effec the upwelling/downwelling processes which further the exchange of warm/cold water. According to when the temperature increases the particles in the water disperse leading to the increase of the salinity dissolution activity, and both processes impact ocean density and the vertical current component. That c increase of precipitation to lead to favourable thermo-saline condition for the development and the pr species in the area. On the other hand, the trend of the horizontal current component, horizontal wind co is decreasing, which allows *Sargassum* species to float at the sea surface. They are easily transported by and the non-tumultuous waves along the shores.

When it rains, sea surface temperature may decreases and could slow down *Sargassum* bloom in the nonetheless, sea surface temperature only is not enough to explain *Sargassum* patterns. A low win increase of the currents' velocity would accelerate the displacement of *Sargassum* species from the sea season as mentioned by previous studies. Indeed, winds and ocean currents will contribute to the throughout the sea surface until they will reach the coast.

That was supported by Hill *et al*. (2013) who reported that the average direction and speed of *Sar* determine using the sum total of movement of the wind and ocean currents velocity and direction. S (2017) in the Lesser Antilles, were able in their study to foresee beachings of *Sargassum* using Altern (AFAI) associated to surface ocean currents. They have computed the average speed of the cu *Sargassum* rafts because *Sargassum* followed the ocean currents circulation. In conclusion, the analy temporal evolution of oceanic parameters could participate to Sargassum species shifting and also ev were not statistically significant, the trends reveal a slow but real evolution in the patterns during the as have an influence on *Sargassum* species distribution. So, detecting and assessing temporal and spatial the implementation of statistical environmental evaluations.

Table 19 Estimation of the variables times series trends characteristics*

Variable	Lbound	Ubound	Trend	Trendp	Tau	Sig	Autocor
Precipitation	-0.041	0.667	0.165	3.301	0.018	0.944	0.704
Salinity	0.000	0.036	0.014	0.560	0.207	0.296	0.650
Temperature	-0.184	0.075	-0.016	-0.327	-0.240	0.162	0.703
U-velocity	-0.003	0.011	0.004	0.076	0.170	0.327	0.457
V-velocity	-0.004	0.003	0.000	0.010	-0.018	0.944	0.143
U-wind	-0.062	0.022	-0.018	-0.727	-0.408	0.699	0.242
V-wind	-0.067	0.089	0.013	0.500	0.408	0.699	0.458
Wind speed	-0.044	0.050	0.023	0.933	0.408	0.699	0.566

Variable	Lbound	Ubound	Trend	Trendp	Tau	Sig	Autocor
Precipitation	-0.041	0.667	0.165	3.301	0.018	0.944	0.704

*

Lbound: The lower bound of the trend's confidence interval.

Ubound: The upper bound of the trend's confidence interval

Trend: The Sen's slope (trend) per unit time

Trendp: The Sen's slope (trend) over the time period.

Tau: Kendall's tau statistic computed on the final detrended time series.

Sig: Kendall's P-value computed for the final detrended time series.

Autocor: The autocorrelation of the final detrended timeseries.

Source: Author’s compilation, 2017

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Climate change is characterized by variation of the temperature and rainfall patterns affecting directly th atmosphere and ocean processes. The result from the research questions has demonstrated that warm ocean parameters and lead to *Sargassum natans* and *Sargassum fluitans* new distribution. The principal motions is the wind (u, v, speed) patterns associated with the horizontal current velocity. The other ocea velocity, salinity, precipitation, sea surface temperature, play an important but indirect role into the sh *Sargassum* species. All of the oceanic parameters interact and varies together in having repercussions or

Moreover, the analysis of the normalized Fluorescence Line Height associated with the recorded g advocate that over this six (6) years, *Sargassum* species have been recurrent along Nigerian coast. The likelihood of *Sargassum* species, the severity, their past spatio-temporal patterns which could be im more external information which could make easier decisions taking for planners and decision-makers differences in the concerned zones. The occurrence of S*argassum* species was confirmed with the analys but the monthly extent of the species fluorescence does not follow the monthly range trends reported by either this corresponds to an undetected *Sargassum* species patterns or another algae specie with almo characteristics.

The coastal population in the sites sampled, perceived the change in the climate and the occurrence of their coast on the water, beaches and shores, not in the lagoons where another specie was identified as they have little knowledge about both phenomena due to their low educational level and limited inf majority, climate change is just a natural variability and it is seen as a change in weather conditions a have several consequences on the respondents' livelihood and activities. In addition, the population c challenges due to climate change and occurrence of *Sargassum natans* on their daily life such as floodi recurrence, long distance browse by the fishermen and fishing disturbance, but they do not have any ada with these events.

Finally, the oceanic variables studied evolve over these last years either with a decreasing or increasing together in influencing each other patterns which empower the mechanisms behind *Sargassum natan* distribution. Thus, *Sargassum* events in Nigerian coast could be mostly explained by how these oceanic to the climatic changes which affect the species.

5.2 Recommendations

This study examined the factors responsible for the spatial distribution of *Sargassum natans* and *Sarg* coast of Nigerian, its link with the changing climate and theirs impacts on coastal population. Nowaday repercussions such as the shift and occurrence of *Sargassum* species constitute a challenge for the scie results, measures should be taken to help the coastal communities to adapt to both events. Thus, the fol are proposed:

(1) Implementing measures to inform, to educate, and to sensitize the population about climate char

(2) Awareness campaign should be launched in order to assist the coastal communities in the ide species strandings,

(3) Sensitization and efforts should be geared towards the determination of the population vul climate change with a view to providing support to them,

(4) *Sargassum* species threaten food security, thus, a realistic evaluation of the threats through currents circulation over West-Africa in order to predict and to manage *Sargassum natans* potential should be organized,

(5) Removal of *Sargassum* species from the open water should be carried out to address the challe pose to fishermen and their fishing activities,

(6) Provision of assistance to the fishermen to help them adapt better to any future climate th occupation,

(7) As several papers praise the chemical benefits of *Sargassum natans* and *Sargassum fluitans*, th be integrated in agricultural project as liquid or biochar fertilizer or integrated in medical proj properties,

(8) Monitoring climate variables in order to deal with any considerable threats resulting from ch rainfall patterns especially with reference to farmers and other workers,

(9) Involvement of all stakeholders especially relevant organizations and agencies in implementing c and mitigation for the population,

(10) More studies about climate change awareness and its impacts should be conducted in various perception based on their pecular conditions.

(11) Further research could assess the role of tides on *Sargassum* upcoming and decomposition, othe *Sargassum* presence in accordance to the nature of the shores meaning exposed or protected shor water pollution.

(12) Finally, further research should focus on how an efficient monitoring model of oceanic varia track the presence of *Sargassum* species and climate trends.

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APPENDICES

Appendix A

QUESTIONNAIRE ON CLIMATE CHANGE KNOWLEDGE AND COASTAL COMMUNITIES PERCEPTION ON THE OCCURRENCE OF *SARGASSUM* SPECIES

A- GENERAL

Date: **GPS coordinates**:…………………….....

State: **LGAs**:

Locality:

Name of respondent:

Gender: Male /_/ Female/_/

Age: >20 /_/ 20-30 /_/ 30-40 /_/ 40-50 /_/ >50 /_/

Household size: less than 4 /_/ 4–6 /_/ 7–9 /_/ 10–12 /_/ 13–15 /_/ 16–18 /_/ <18 /_/

Educational level: No formal education /_/ Primary school /_/ Secondary school /_/ Tertiary education /_/

Ethnics group:…………………………………………………………………….

Major occupation:…………………………………………………………………….

Source of income: …………………………………………………………………...

B- AWARENESS ABOUT CLIMATE CHANGE

1. Have you ever heard about climate change? Yes /_/ No /_/
2. And if yes, from which sources did you hear it ? Media /_/ Village head /_/ Neighbours /_/ Weather station /_/ School /_/ Own observation /_/ Researchers /_/ Other /_/
3. What do you understand climate change means?(tick many as possible)

-Change in temperature

-Change in the environment

-Change in weather conditions

-Change due to human pollution

-I do not know

-Other ……………………..…………………………………………………………………….

4. What do you think is the cause of climate change? Human activity /_/

Natural variability /_/

5. Do you think climate change has effect on your community? Yes /_/ No /_/
6. If yes, what kind of effects? ……………………………………………………

……………………………………………………………………………………………….

7. For the issue listed below please give your perception

Decreace increase Constant Do not know

Sea level…………………… /_/ /_/ /_/ /_/

Rainfall intensity…………. /_/ /_/ /_/

/_/

Rainfall shift………………... /_/ /_/ /_/

/_/

Wind speed…….…………… /_/ /_/ /_/

/_/

Sea pollution

(nutrients supplying)………… /_/ /_/ /_/

/_/

Other(specify)………………………………………………………………………….

8. What do you think are the impacts of climate change on the following?

Decrease increase

Constant Do not know

Drought frequency………….. /_/ /_/ /_/

/_/

New disease…………………. /_/ /_/ /_/

/_/

Flooding……………………… /_/ /_/ /_/

/_/

Difficulty of navigation

due to wind………………. /_/ /_/ /_/

/_/

Coastal erosion…………...   /_/   /_/   /_/
/_/

9. What impact do you think climate change has on the following?

Fishing products…………...   /_/   /_/   /_/
/_/

Shrimps, crabs products…...   /_/   /_/   /_/
/_/

Crop yield………………….   /_/   /_/   /_/
/_/

Distance fishers do………..   /_/   /_/   /_/
/_/

to get fish

Others(specify)…………………………………………………………………...……
……………………………………………………………………………………….

10. Which of the following do you think affects your community mostly as a consequence of climate change?

Drought frequency…………..   ..………………..../_/

New disease…………………………………..../_/.

Flooding……………………………………../_/

Distance length fishers have to do…………/_/

Difficulty of navigation

due to wind………………………………./_/

Coastal erosion…………………………./_/

None…………………………………..../_/

Other(Specify)…………………………………………………………………………..

C- PERCEPTION OF THE PEOPLE ON *SARGASSUM* OCCURRENCE

1. Have you noticed the occurrence of algae species on the sea or along the coast the last years? Yes /_/ No /_/
2. If yes, since when? Less than 5 years /_/ 5-10 years/_/ more than 10 years /_/
3. Is there a specific season of abundance? Yes /_/ No /_/

   Which season?…..……………………………………………………………….
4. Do you think that the appearance of these species can be linked to climate change? Yes /_/ No /_/

   Why…………………………………………………………………………...
5. Do they affect your activity? Yes /_/ No /_/
6. If yes, in what way do they affect your activity?……………………………….…
7. For you which area and persons are more touched by this?

………………………………………………………………………………………

D- CONSEQUENCES OF CLIMATE CHANGE AND *SARGASSUM* SPECIES OCCURRENCE ON LIVELIHOOD

1. List three major consequences of algae presence in terms of intensity of the problem.
   - ………………………………………………………………………………
   - ➢ ……………………………………………………………………………...
   - ………………………………………………………………………………

2. On the following, has climate change any impact on your household?

- Activity……………………………………………………………………
- Income………………………………………………………………………
- Feeding……………………………………………………………………
- Welfare……………………………………………………………………
- Health………………………………………………………………………
- Other………………………………………………………………………

3. On the following, has *Sargassum(algae)* occurrence any impact on your household?

- Activity…………………………………………………………………...
- Income………………………………………………………………………
- Feeding…………………………………………………………………...
- Welfare…………………………………………………………………...
- Health……………………………………………………………………….
- Other……………………………………………………………………...

E- ADAPTATION MEASURES

- **Adaptation measures of climate change**

1. Do you have adaption measures of climate change? Yes /_/ No /_/

If yes, which ones………………………………………………………………

2. During these period, did you received assistance ? Yes /_/ No /_/

From Relatives /_/ Friends /_/ NGO /_/ Government /_/ Other /_/………………………………………………………………………………..

Which type of assistance?

………………………………………………………………………………………What recommendations can you propose to resolve this situation and to make improvement to your life within this area?

....………………
…………………………………………………………………

- **Adaptation measures of algae species occurrence**

3. Do you have adaption measures of algae species? Yes /_/ No /_/

If yes, which ones………………………………………………………………………

4. During these period, did you received assistance ? Yes /_/ No /_/

From Relatives /_/ Friends /_/ NGO /_/ Government /_/ Other /_/………………………………………………………………………………..

Which type of assistance?

………………………………………………………………………………………

5. What recommendations can you propose to resolve this situation and to make improvement to your life within this area?

....…

Appendix B

SOME PHOTOGRAPHY OF THE VISITED AREAS


Wind damages
Interview seance with some respondents


Echornia crassipes in Ojo, Lagos State

Appendix C

NUMBER OF CODINGS FOR EACH CODE

Code name	Number of codings associated	Code name	Number of codings associated
Abnormal rainfall	90	Dry season	8
Activity	125	Feeding	115
Change due to human pollution	13	Fish quantity	128
Affect fishermen	98	Flooding	129
Affect fish seller	27	Health	105
Change in temperature	113	High temperature	18
Change in the environment	61	Human activities	54
Change in weather conditions	131	Income	127
Coastal erosion	53	Link to climate change	46
Crop yield	58	Make sea, shores and beaches	88
Difficulty of navigation due to strong wind	107	Make water dirty	21
Distance browse by fishermen	118	Natural variability	92
Disturb boat transport	41	Natural variability and human activities	12
Disturb fishing	105	New disease	126
Drought frequency	56	Occurrence of Sargassum	111
Odor	30	People activity	57
People feeding	70	People health	5

People income	57	People welfare	5
Rainfall intensity increase	125	Rainfall shift increase	90
Rainy and dry season	53	Rainy season	41
Sea level increase	75	Welfare	92
Strong wind	69	Temperature variability	100
Shrimps, crabs quantity	83	Sea pollution	73
Wind speed increase	131		