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DEPARTMENT OF PLANT BIOLOGY
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A Contribution to the evaluation of climate variation in the South Region of Cameroon and its influence on road construction: *Case of* DJOUM – *Mintom Congo Border Road*

Dissertation Submitted in Partial Fulfillment of the Requirement for the Award of a Masters' Professional Degree in Environmental Science

Option: Environmental Cleansing and Restoration

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DEDICATION

To my mother

Madam HOMBAWI Kabeing Beatrice

APPRECIATION

This research have been achieve by my personal effort and with the help of many others that have sacrifice a lot to see that the final objectives of this study were obtained, In this regard, I will like to express my sincere gratitude to the following individuals:

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LIST OF ABBREVIATIONS

UNFCCC: united Nation Framework Convention for Climate Change

COP: Conferences of the Parties

NAMAs: Nationally Appropriate Mitigation Actions

NAPA: National Adaptation Plan of Action

RPP: Readiness Preparation Plan

NRN: National road number

GHS: Greenhouse gas

CO^2 : Carbon dioxide

SPSS: statistical package for social science

PZ : Project Zone

EIA : Environnemental impact assessment

CCTP : Cahier des clauses techniques particulars

GPS : Global positioning system

EMP: Environmental management plan

ABSRACT

This study of climate variation in the south region of Cameroon and its influence on road construction work, case of Djoum-Mintom Congo border road have as objective to evaluate the present climate trends in the south region with data from the Ebolowa weather station from 1960 t0 2010 and how this variation may influence the Djoum -Mintom road work

To achieve these objective rainfall data was collected from the Ebolowa weather station while daily and monthly soil excavation work report was collected from the enterprise. This was then finalist with field observation and questionnaires design for the road engineers and villagers in the project zone.

The result of this studies shows that the south region has an average of 1807 mm of rainfall in an average of 165 days. Two rainfall regimes were identify, the bimodal with four seasons. Two dry and two rainy season and occupies 88 % of the region climatic system. The trimodal with six seasons three dry and three rainy seasons and occupies 22 % of the region climatic system. Generally the south have four seasons, a short rainy season from March to June and a long rainy season from August to November. While the long dry season is from December to February and the short dry season from July to August. Despite this seasonal repetition, rainfall and extreme high temperatures are experience in all the months of the year within the 50 years study period, with constant seasonal displacement and compensation within the seasons. Generally they is a constant decrease in rainfall and number of days of rainfall but rainfall is decreasing faster than the number of days and the rainfall patterns are more or less irregular. This constant displacement of season makes it difficult for the road construction enterprise MNO VERVAT Cameroon to programme its activities. Soil excavation and concrete application are weather sensitive due to the unworkable nature of the soil with rain and the early cracking of concrete in intense rain or temperature.

Key word: Climate variation, Rainfall and number of days of rainfall, seasonal displacement. Soil excavation, concret pouring. Meteorological station.

RESUME

Cette étude sur la variation climatique dans la région du Sud Cameroun et son influence sur la construction de la route cas de la route Djoum _Mintom frontière Congo a pour objectif d 'évaluer le mode présent du climat dans région du sud et son influence sur la construction de la route avec des données provenant de la station météorologique de Ebolowa de 1960 a 2010.

Pour attendre ces objectifs les donnes pluviométriques sont prises à la station météorologue d'Ebolowa et les comptes rendues mensuels et journaliers de terrassement de l'entreprise sont collectes. Ceci a été finalisée par la administration de questionnaire au niveau de l'entreprise et des aux autochtones dans la zone de projet et un descente de le terrain.

Le résultat de ces études montre que la région de sud a deux régimes saisonniers, la bimodal avec quatre saisons avec 88 % de régime et la tri modal avec six saisons et 22 % de régime de climat.

Généralement le sud a une petite saison de pluies ver Mars à Juin et un longue saison de pluies ver Aout à Novembre .Alors que la longue saison sèche va de Juillet à Aout .Malgré la répétition de saison la pluie et la haute température se sont expérimentées dans tous les mois de la année durant les 50 années qu' ont mis l'étude ,avec une succession constante de saison et la compensation entre les saisons. Généralement il, y a une baisse de pluie et des nombre de jours de pluie, mais la pluie baisse plus que le nombre de jour de pluies. Le régime de pluies est plus ou moins irrégulier. Cette constante succession de saison ne rend pas la tâche facile à la société MNO VERVAT Cameroun de programmer leurs travaux. Le terrassement et le bitumage sont sensibles au climat car le sol mouille rend presque impossible le travail, et la pluie détruit le bitumage.

Mots clés: variation climatique, pluies, succession saisonal, sol mouille, terrassement, bitumage, station météoritique, donnes pluviométriques

CHAPTER I. GENERALITIES

I. INTRODUCTION

I.1 Context and justification

Climate is a dynamic phenomenon that varies and changes continually, with long-term warming and cooling cycles. Recent rapid and extensive changes are too extreme to be ignored. A global increase of 0.6 ^{o}C has been observe in the last century (Anonymous, 2001), and is linked to the modification of atmospheric composition with greenhouse gases (GHG). Temperatures over Cameroon have been on the increase since 1930 and this is in line with the global increase of 0.6 ^{o}C (Ayonghe, 2001). In Cameroon, carbon dioxide (CO_2) the major GHG is likely to have built up in the atmosphere because of deforestation and bush fires supplying CO_2 to the atmosphere, which means the loss of the major carbon sink. One of the significant effects of the increase in global temperatures has been the decline in mean annual rainfall experience all over the country.

Africa's emissions of climate change-inducing carbon dioxide are still low, estimated to be only 3.6 % of the world's total. Moreover, the continent's vast forest reserves serve as a significant sink for carbon dioxide, and thus play an important role in sinking the emissions of industrialized countries. Although Africa has not historically contributed to climate change, and its forests have provided a significant sink for the carbon emitted by industrialized countries, it is predicted that the continent will be the most affected by the adverse effects of climate change, as many aspects of African economies are extremely climate sensitive and they are less able to cope with this impacts. (Molua and Parry, 1990; Winter *et al,* 1999; Anonymous, 1997).

Cameroon is a signatory to the United Nation Framework Convention for Climate Change (UNFCCC) and the Kyoto Protocol. More recently the country has participated in the Conferences of the Parties (COP).The country has submitted a set of Nationally Appropriate Mitigation Actions (NAMAs) to the UNFCCC in 2010 and have developed a REDD Readiness Preparation Plan (RPP) and a National Adaptation Plan of Action (NAPA) to prepare for future climate change mitigation.

Climate variation phenomenon poses a great threat to humanity, the built environment and civil engineering society. Extreme weather events, rainfall and air temperatures make road building more expensive to put up as the type of materials and foundation employed on an adversely wet soil will have high cost implications. Weather elements (temperature, rainfall, wind) affects the health and safety of all site workers and labourers, particularly those working out doors on construction sites and this in turn will delay site construction activities and associated costs (Anonymous, 2010). The regime of soil saturation is important for the conception and dimensioning of the road drainage system, the workable nature of soil, as well as the temperature regime for material resistance (asphalt).

Planning of construction projects, involved a study of the climate variables of the project zone for best scheduling of activities (Clagton, 1989). The entrepreneur executing the project has to evaluate the meteorological circumstances of the project zone susceptible to delay or stop the work, since these factors influences the delay of project achievement, its income as well as the efficiency of the company.

The enterprise MNO VERVAT Cameroon is in charge of the Djoum - Mintom Congo border road construction project. This project finance by Africa Development Bank (ADB), and Cameroon has two phases .The first is a tarred road of 83 km from Djoum to Mintom, and the second phase will involves maintenance of a 120 km straight road without tarred from Mintom to the Congo border in the south region of Cameroon. The project started since two years ago and since then, they have experience rainfall which they consider exceptional from what they presume from the date of signing the contract.

I.I.2 Objective of the study

I.I.2.1 General Objective

The general objective of this work is to contribute to the evaluation of climate variation in the south region of Cameroon and its influence on road construction work, the case of Djoum-Mintom Congo border road project in the south region of Cameroon.

I.I.2.2 Specific objectives

To achieve this general objective, the following specific objectives where formulated:

- evaluate the evolution of rainfall in the south region from 1960 to 2010;

- evaluate the typology of rainfall in the south region from 1960 to 2010;
- evaluate the Djoum-Mintom Congo border road construction activities and how they can be influence by climate;
- make a correlation between climate and the Djoum- Mintom Congo border road construction.

I.2 Literature review

I.2.1 General Concepts of climate

The road construction industry is highly sensitive to weather conditions. This sensitivity arises from the fact that certain types of weather conditions must exist for the various construction activities to operate efficiently. For example, soil excavation cannot be efficiently carried out during periods of excessive rainfall, concrete pouring is hazardous when temperatures are below freezing. Because of this sensitivity to ambient weather conditions, it is important for contractors and contracting firms to understand the climate variation in a project zone (PZ).

I.2.1.1 CLIMATE

Climate is define as the average or typical weather condition observed over a long period of time at least 30 years for a given geographical location.

By definition climate variation refers to changes in one or more climatic variables (rainfall, temperature, wind etc.) over a specified time (Anonymous, 1990). While climate change are the long-term shift in the climate of a specific location, region or planet. This shift is measured by changes in features associated with average weather, such as temperature, wind patterns and precipitation (Ayoade, 1988). Thus variation in climate actually result to changes in climate. It is now widely accepted that the climate varies and changing all over the world. The global mean temperature increased by 0.6 °C in the last century, and the 1990s were particularly the hottest years (Anonymous, 2001). On whole, wetter periods have been succeeded by drier periods and cold periods by hot ones (Peel, 1966). Climate models predict that mean annual global temperature will increase by 1-3.5 ^{o}C by 2100 and global mean sea level will rise by 15-95 cm with changes occurring in the spatial and temporal patterns of precipitation .(Anonymous, 1990,1997).

I.2.2 Recent Climate Trends in Cameroon

Cameroon often described as “Africa in miniature” as the country exhibits all major climates of the continent. The Guinea equatorial, equatorial monsoon, tropical humid and soudano sahelian. The country has two rainfall regimes. The unimodal and bimodal system of rainfall. These two shows a gradual decrease in rainfall and an increase in temperature.

I.2.2.1 Rainfall regime in Cameroon.

In Cameroon the mean annual rainfall has decreased by 2.9 mm per month i.e 2.2 % per decade since 1960, experience particularly in 2003 and 2005.Although the dense rainforest region continues to include some of the wettest places on earth (Lambi, 2001). This rainfall deceases from the south (the coastal region and the southern plateau) to the north (the Adamawa plateau and the Chad plain). Variation of rainfall from year to year and sporadic floods and drought are significant. The variability decreases southwards, westwards and attitudinally. A comparison of the years with the highest and lowest rainfalls shows a marked variability. The years with extreme rainfall have a tendency to cluster, thereby indicating extreme dry and wet periods (Beauvilain, 1985). There has been a succession of droughts and floods in the northern part of Cameroon with increasing frequency over time. These floods have always been preceded by a period of drought. These flood periods coincide with that of La Niña, while the years of drought have often coincided with those El Niño. Whereas the El Niño episodes may be the origin of most droughts, it is important to note that the severity of the problem is directly linked to the extent of environmental degradation. However, despite these fluctuations between floods and droughts, climatic data shows that the rainfall over the years has been on the decline in most part of the country (Ayonghe, 2001).

.I.2.2.2 Temperature regime in Cameroon.

Average temperatures in Cameroon have been increasing since 1930 (Ayonghe, 2001). The net rate of increase has been 0.95 ^{o}C between 1930 and 1995. This increase certainly falls in line with the global trend of 1.5 ^{o}C (Anonymous, 1992) which is link to the modification of the atmosphere with greenhouse gases. Available data indicate increasing trends in the frequency of rainfall days, with decrease in the quantity of rainfall annually.

I.2.3. Climate of the south region of Cameroon

The South region is located in the equatorial climate zone. The south experience four seasons repeated within the year.

Two rainy season, a long rainy season from mid-August to mid-November and a short rainy season from mid-March to May. Two dry season, a long dry season from mid-November to mid-March, a short dry season from June to mid-August. (Anonymous, 2009)

The south climate is characterized by the forest that plays a role in the dynamism of the atmosphere and the mass movement of the air it produces and also generates rain within the year. The only meteorological station in the south zone is in Sangmélima and Ebolowa. That of Sangmélima functions from 1975 to 1993 before haven a break down, and since then rainfall data has been limited to daily values. The only functional station in the region is that of Ebolowa.

I.2.4 Civil engineering activities and their sensitivity to climate variables

The construction industry is important in the economy of every nation as it contributes to the process of development. The construction industry comprises a wide range of businesses, involved in engineering standards, building design, and the construction of various types of materials and structures. This sector is affected in many ways by climate change and extreme weather events. Knowledge about short term weather and long term climate conditions are essential to adequately design and successfully manage construction projects (Anonymous, 2010).

1.2.4.1 Rainfall influence on civil engineering work.

Most road construction activities require dry conditions, such as preparing pavement or road soil excavation. Pavement preparation involves soil excavation and compaction that cannot be carried out on a water saturated soil. This is because after rainfall of above 5 mm the soil becomes muddy and cannot be work upon .This can cost contractors thousands of dollars per day if not properly planned for in advance (Naoum, Fong, and Walker, 2004).

Severe weather events, impact costs associated with transport and delay delivery of construction products and materials, delay site construction activities and programming, increase site construction costs due to increased mitigation measures, such as large scale treatment of construction water run-off which may have indirect effects to local economies (Anonymous, 2006).

1.2.4.2 Temperature influence on civil engineering work.

High temperature, reduces the setting times and strength of concrete (Concrete loses moisture more rapidly during placing. The hardening process of concrete takes place during the very early ages of a concrete lying. During this early stage, when freshly placed, concrete is very sensitive and could easily crack if subjected to high temperature or rainfall. The method of handling the concrete structure during these first few days or weeks is very crucial for its final performance and durability (Clark, Priest, Treby, and Crichton, 2002)

Also increase in temperature will increase evapotranspiration thus reducing the volume of water in the project zone i.e. water needed for construction.

Generally increased extreme weather events and air temperatures will directly affects the health and safety of all site workers and Laborers, as diseases such as malaria are likely to have wider ranges particularly those working outdoors on construction sites. This in turn will delay site construction activities and associated costs (Anonymous, 2009). Knowledge about short term weather and longer term climate conditions are essential to adequately design and successfully manage construction projects (Anonymous, 2010**).** The construction industry may be more vulnerable to climate risk than other sectors due to short term reaction of other stakeholders to perceived risks (Hertin *et al*, 2003)

The public sector most take steps such as changing the existing construction norms, so that infrastructures will be capable of coping with the future climate change (Schneider *et al*, 2007; and Anonymous, 2004). Taking in to consideration weather events as major challenges for road construction could perhaps be the basis for making long regulations and decisions (Koetse *et al*, 2009).

I.2.5 DESCRIPTION OF THE STUDY ZONE

I.2.5.1 Geography of the study zone

The south region of Cameroon is located in the southwestern and south-central portion of the Republic of Cameroon. It is bordered to the east by the East Region, to the North by Centre Region, to the Northwest by the Littoral Region, to the West by the Gulf of Guinea (part of the Atlantic Ocean), and to the South by the countries of Equatorial Guinea, Gabon, and Congo. The South covers 47.191 km^2 thus take 5 % of the country's surface area. The major ethnic groups include the various Beti-Pahuin peoples, such as the Ewondo, Fang, and Bulu, having 514.336 inhabitants thus 4 % of the country's population.

I.2.5.2 Physical description of the study zone

1.2.5.2.1 Geology

The rock consists primarily of metamorphic rock, particularly gneiss. However, the land consists of many faults zone around the border with the Centre Province. Granite deposits occur along this line. The soil is primarily ferrallitic except for the southwestern portions near the border with Equatorial Guinea and moving north to Ebolowa, which it is mixed. Due to high amounts of leaching, the South's red earth is only marginally productive.

I.2.5.2.2 Drainage

Several river systems drain the South Province. The most important of these is the Nyong, which forms part of the border with the Littoral region. The coastal Ocean division is drained by two rivers, the Lokounje in the north and the Lobé in the south. The Ntem, or Campo, rises in the east of the region and flows along or just north of the southern border to the town of Campo. All of these rivers empty into the Atlantic Ocean.

The Dja and Lobo Rivers flow through the easternmost division of the province, splitting south of Bengbis and encompassing the Dja Reserve. These two rivers form part of the Congo River basin.

I.2.5.2.3 Relief

The South Province begins at sea level on the coast. The land slowly climbs throughout the Kribi-Douala basin, which averages 300–600 meters in altitude, until it reaches the South Cameroon Plateau with elevations of 500 to 1000 meters above sea level. Rocky promontories on the coast and rolling, tree-covered hills inland characterize the land. The Ntem Massif near Ebolowa is the province's highest point at 1400 meters.

I.2.5.2.4 Climate variability in the South region

The climate of the South Province is Type A or Guinea-type climate. Humidity is high, and precipitation averages 1500–2000 mm per year in the interior and 2000–3000 mm per year in the coastal region. The coast from the north of Kribi south to Ebodjé gets as much as 4000 mm of rain per year. Temperatures are relatively high as well, averaging 24 ˚C and 26 ˚C from Kribi North along the coast.

The Guinea-type climate affords alternating dry and wet periods. The year begins with a long dry season that runs from December to May. This is followed by a light wet season from May to June and a short dry season from July to October. A heavy wet season begins around October and lasts through November.

I.2.5.2.5 Biology

The South is almost entirely covered with rain forest, the exception being a small tract of mangrove in the coast, south of Campo. Much of this forest has been intensely exploited by logging, allowing sunlight to penetrate to the forest floor and for thick undergrowth to flourish.

Today, the only relatively untouched forest is located in a handful of nature reserves. The Dja Reserve (*Réserve du Biosphère du Dja*) covers 5,260 km² in the northeastern portion of the province and the south-central portion of the neighboring East. The Campo Reserve (*Reserve du Campo*) covers 2,640 km² in the southwest on the border with Equatorial Guinea. Finally, the Mangame Gorilla Sanctuary (*Sanctuaire à Gorilles de Mangame*) covers 1,224 km² on the Gabon border. The south rain forest supports abundant wildlife, including some of Cameroon's last populations of chimpanzees, gorillas, and elephants. All of these are becoming increasingly rare due to poaching and deforestation. More numerous are the various monkey, bat, and bird species. Other common animals include pangolins, porcupines and other rodents and genets.

I.2.5.2.6 SOCIO ECONOMIC AFFAIR

The area's economic stronghold, however, is the port of Kribi. With ocean access and vast tracts of forest, the South is home for many industries. Timber is a substantial part of the region's economy, and various logging companies are operating in the area. However, because the largest trees within the South itself have mostly been harvested, the region is increasingly being used as a transport network for logging vehicles from Equatorial Guinea, Gabon, and Congo on their way to the ports of Kribi and Douala. Much of the South's electricity is produced in the hydroelectric power stations in Ntem and Ma'an rivers.

The South also has a fair amount of mineral wealth. Iron ore is mined near Campo and Kribi. Natural gas is found offshore of Campo, and a Kribi-based plant has been processing this since the 1980s. But more importantly, the South Province is located at the terminus of the pipeline. The pipe's month is located just south of Kribi, a fact that promises to bring in high revenues for both Cameroon and the region.

The majority of farming in the South Province is done at the sustenance level. Plantains are the major crop grown, with coco yams being common north of Ebolowa. Maize, groundnuts, cassava, yams, beans, and other foodstuffs are raised in more modest quantities.

CHAPTER II: MATERIALS AND METHODS

II.1 PRESENTATION OF STUDY ZONE

The southern region of Cameroon is located in the southwestern and south-central portion of the Republic of Cameroon. It is located at latitude 02º41º N and longitude 12º35º E and is bordered to the east by the East Region, to the north by the Centre Region, to the northwest by the Littoral region, to the west by the Gulf of Guinea (part of the Atlantic Ocean), and to the south by the countries of Equatorial Guinea, Gabon, and Congo. The South covers 47.191 km^2 thus takes 5 % of the country's surface area. This forest region is occupied by two large ethnic groups. The Bantous, represented here according to their numerical importance the Boulous between Samgmalima to Djoum, the Fang between Djoum and Mintom, and the Kaka between Mintom to the Congo border. The second group is the pygmy of Baka who live in perfect harmony with nature.

On the geographical plan, the project is in the south region of Cameroon precisely around Djoum, Mintom to the Congo border in the DJA and lobo division. The roads tracks are practically in use thanks to timber exploitation companies in the zone. The road project crosses through several villages , thus the most important are Meyos, Obam, Avebe, Messam, Melen ,Alop, Mbame'la ,Akom, Mbouma, Mekoto, Koungoulou, Zouatou, Bindom, Zoulabot, and Mintom. This region is a forest zone and covers 47.191 km^2 thus taken 5 of the country's surface area and has a population density of 514.336 inhabitants thus 4 of the country's population.

The entire zone is influence by the equatorial climate with a rainfall between 1.450 to 1.650 mm from Sangmelima Cameroon in the south, to Katta Congo in the East.

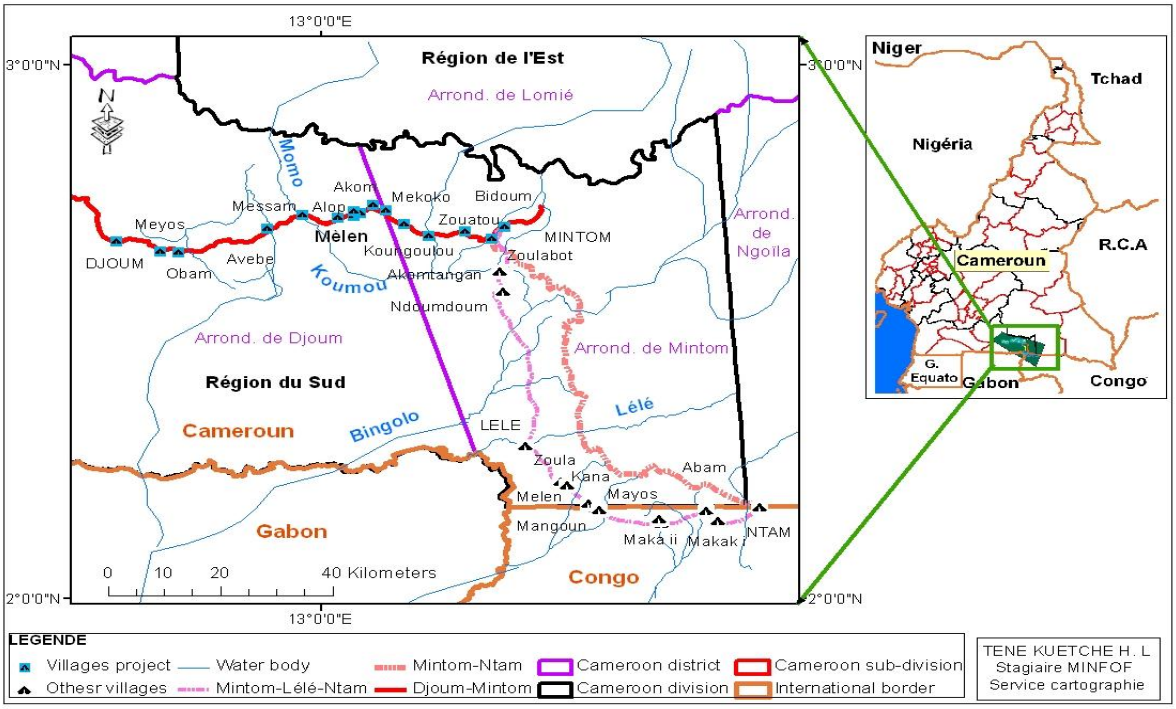


Fig.1. Location of the study zone

II.2 MATERIALS

The materials used for this research include:

- Daily work records from the enterprise;
- rainfall data from the Ebolowa weather station;
- camera;
- note book and pen;
- boot;
- computer machine;
- Cameroon national road map;
- GPS.

II.3 METHOD

II.3.1 choice of study area and data collection

II.3.1.1. Choice of the study area

The study area is a forest zone, which is an integral part of the five agro-ecological zones of Cameroon. The weather station chosen for this study is the Ebolowa weather station. It is located at 2 ° 55' north latitude and 11° 9' East longitude at an altitude of 1399 m and the only station close to the study area Djoum.

II.3.1.2. Data collection

II.3.1.2.1. Primary data

Primary data will be collected from direct field observation, questionnaires administration and oral interviews with the road workers, and villagers in the PZ.

II.3.1.2.1.1. Size and choice of the sample population to be investigated.

Using Neymans, law of 1980, on sample size distribution within population of different category or on the determination of sample size to be used to obtain a sample that will represent different category of people, the same amount of people in the different categories to be investigated was used. (Androing et al, 1980).

Thus to realist this investigation within the enterprise MNO VERVAT Cameroon, a systematic random sampling is used and the theoretical size of the sampling population is determine with an estimated prevalence of 40 %, an error parameter of 1.96 with 4 % precision. The formulae to have the maximum sample size on which the research will be effective is as follows,

$$N = \frac{1 \, X \, t^2 \, X \, P \, (1 - P)}{d^2}$$

$$N = \frac{1 \times 1.96^2 \times 0.4(1-0.4)}{0.05^2}$$

N = 188.16

Where N = sample size

t = Error risk parameter of 4 % which correspond to 1.98

P = Awaiting result 40 %

d = Degree of confidence which is standard 5 %

The targeted population comprises managerial staff, civil engineers, drivers, other field workers in the enterprise and the villagers.

Respondents were requested to measure the level of significance they attach to factors that could influence road construction project, perception on climate variation. The responds to the questionnaires were analyze using excel.

II.3.1.2.2. Secondary data

These include rainfall data collected from the Ebolowa weather station, daily and monthly work record from the enterprise. The rainfall data were processed through SPSS because of the large nature of the data, while the work records where analyzed using Microsoft excel 2007.

II.3.2. Data analysis

II.3.2.1. Calculating the monthly and annual average rainfall and number of days of rainfall.

The average monthly rainfall and number of days of rainfall is obtained from the following equations: AR = Σ (Rx) / Nb and EM = Σ (Nx) / Nb (Audroing *et al;* 1980). where

RX= monthly volume of rainfall in mm;

Nb = total number of months

AR = average monthly rainfall in mm

Nx= number of days of rainfall per year in days

Nb = total number of months/year;

EM = average number of days of rainfall per year, in days.

II.3.2.2. Calculating the average seasonal rainfall and number of days of rainfall per season.

The average seasonal rainfall and the number of days of rainfall during the rainy season are obtained from the following equations: $SP = \frac{\Sigma(PX)}{Nb}$ and $NS = \frac{\Sigma(NX)}{Nb}$ where

SP= seasonal volume of rainfall collected in mm;

Nb =total number of months during the rainy season;

Px=average rainfall per season in mm;

Nx=number of seasonal days recorded in days;

Nb =total number of months during the season;

NS=number of seasonal rainfall days, in day.

In this study, the dates of the beginning and end of rainfall will be determine using the first day criteria i.e. from the 1^{st} of January 1960 when we register more than 20 mm of rainfall in 1 or 2 days without a dry episode of more than 7 days in the rest of the month. The dates of the end of rainfall are determine when we register less than 20 mm of rainfall without a cumulative rainfall in 7 days (Audroing *et al*, 1980).

II.3.2.3.Calculating rainfall variation from the average rainfall and number of days of rainfall

Variation from the average rainfall is calculated based on the following statistical formulae:

Eave (R) = Ri – Rm and Emoy (**Nb)** = NBRI - NBRM where:

Eave (R) =variation from the average rainfall;

Ri =rainfall in a given year in mm;

Rm =average rainfall recorded in a given time interval;

NBRI= Number of rainfall days in a given year;

NBRM=Average number of days of rainfall over a given time interval;

Emoy (Nb)= variation from the average number of days of rainfall.

II.3.2.4.Calculation of the percentage seasonal rainfall at the Ebolowa station

The percentage seasonal rainfall is the sum of the total rain collected per season on the total annual rainfall recorded. It is obtained from the following formula:

$$\% \text{ R (season)} = \frac{\Sigma P \ (season)}{p \ (total \ annual)} \times 100$$

With R =Rainfall in mm

CHAPTER III. RESULTS AND DISCUSION

III.I. RESULTS

III.1.1. Evolution of rainfall patterns in the south region of Cameroon from 1960 to 2010

III.1.1.1. Evolution of the average monthly rainfall patterns

In an average monthly scale, rainfall and number of days of rainfall evaluate in the same pace (Fig 2) .Its rains 1807 mm a year in 165 days. Four seasons are observed namely two dry seasons and two rainy seasons. On a monthly scale, the long dry season is concentrated between the months of December to February, and a short dry season in July and sometime extends to August. The long rainy season which lasts for four to three months is spreads from August to November and have an average rainfall of 718 mm, while the short rainy season is from March to June and have an average rainfall of 765 mm. The long and short dry season have an average rainfall of 165 and 175 mm respectively.

The number of days of rainfall changes at the rhythm of the four seasons per year. The month of October which records 23 days of rain, is the most spread during the long rainy season. Meanwhile, the months of December and January which registers less than 05 days of rainfall each year is the least.

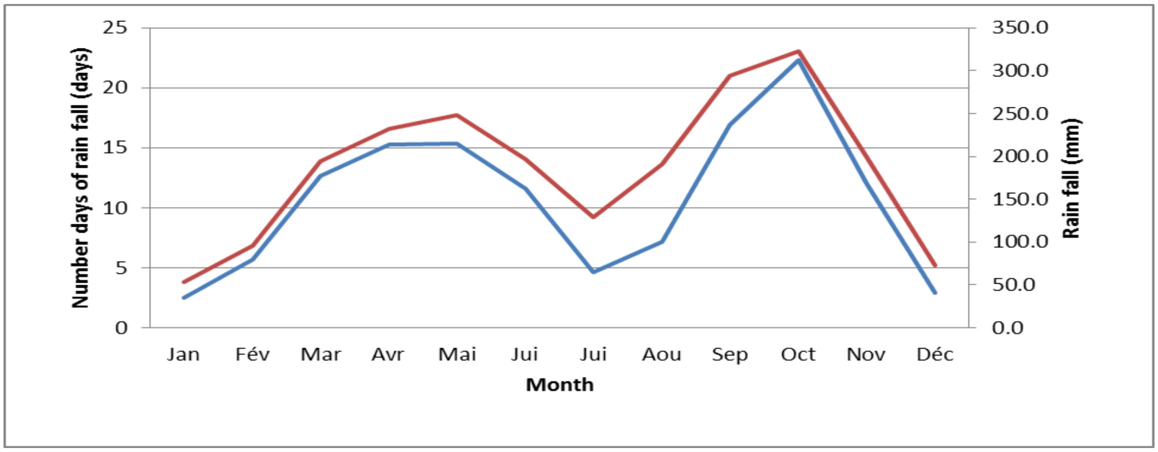


Fig. 2. Evolution of the average monthly rainfall in the south region from 1960 to 2010.

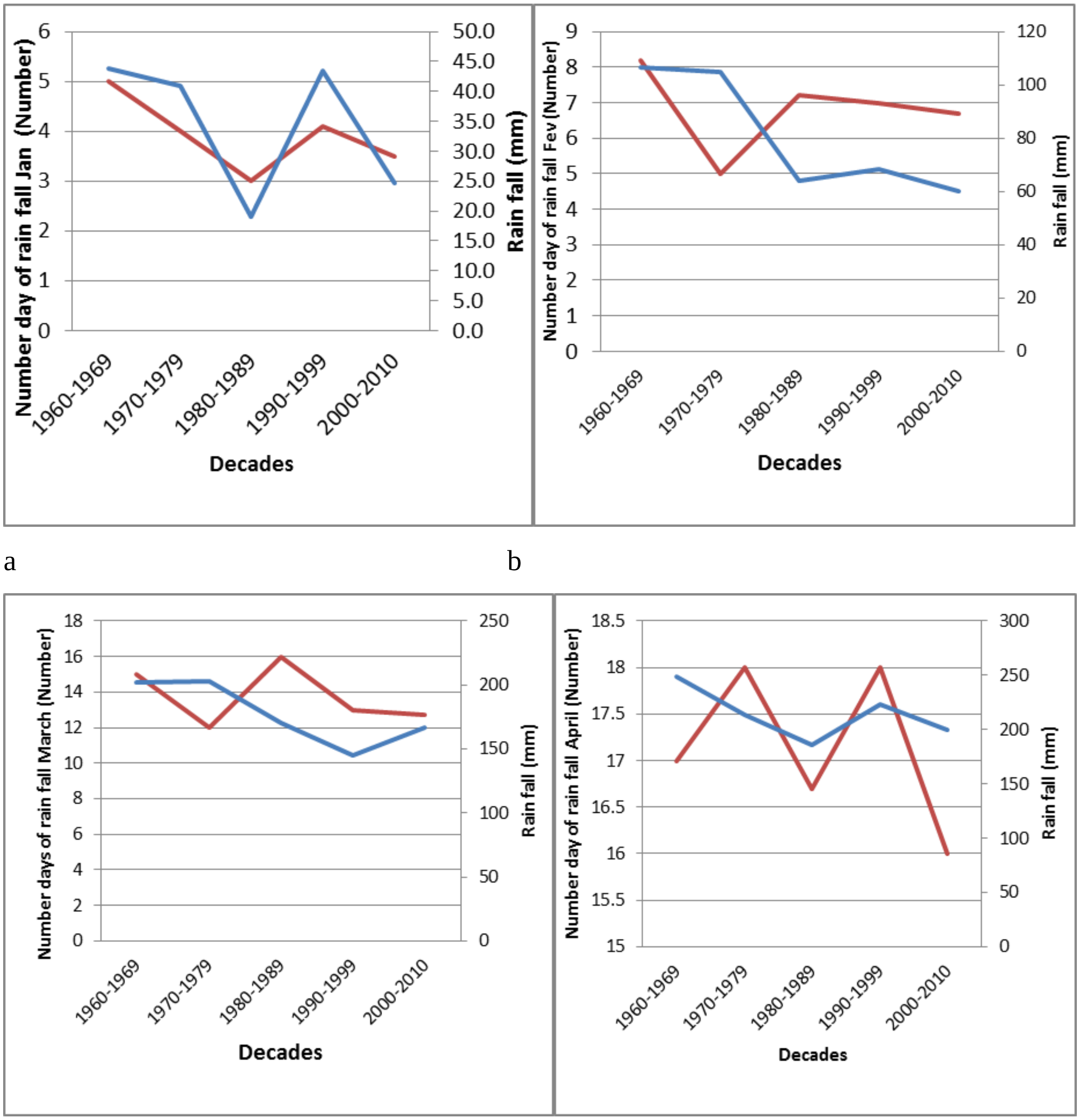
Number days of rainfall Rainfall

III.1.1.2. Evolution of monthly rainfall in the south region from 1960 to 2010

Data of Figure 3 to 5 shows that there are no months without rainfall in the south region over the study period. The months of January, February, March, April, May, October, November and December records a simultaneous decrease in rainfall and number of days of rainfall. Meanwhile, the months of July and August have increasing rainfall in the number of days of rainfall recorded. The months of June and September on the contrary have a contradictory rainfall evolution, while rainfall is decreasing; the number of days of rainfall is gradually increasing.

A decadal observation shows that the decline in rainfall observed in the months of January, February, March and April (fig 3) is especially occasioned by the decrease record in the first, second, third and fifth decades. Only the fourth decade shows an increase in rainfall. The months of May, June, July and August record a decline in rainfall from the first to the fourth decade. Here, only the fifth decade is increasing. The months of September, October, November and December show a decrease in the first, third and fifth decades, while the second, fourth are increasing.

The distribution in decades the number of days of rainfall reveals that the general decline in the months of January, February and March is mainly influenced by the sharp drop observed in the first, second and fifth decades. In April, May and June, we observe decrease in the third and fifth decades, while they are a high increase in the second and fourth decades. The months of July, August, October and November recorded their sharp decline in the fourth and fifth decades while the first, second and third decades are increasing. During this period, the months of September and December record a decrease in the first two decades, while the fourth decade falls sharply.

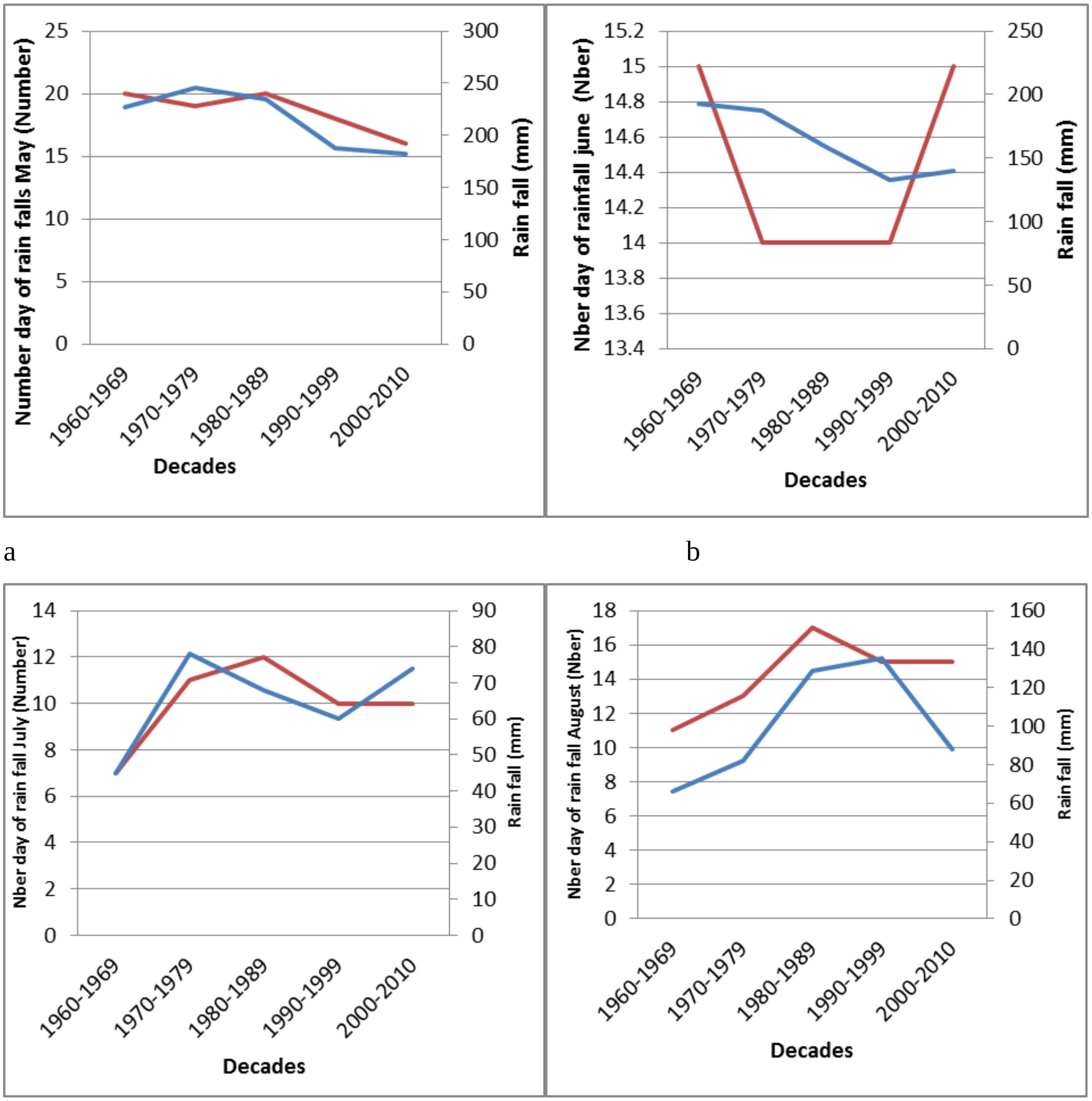


a b

C D

Fig.3. Evolution of monthly rainfall in the South region from 1960 - 2010 (a) January (b) February (c) march (d) April.

Rainfall Number days of rainfall



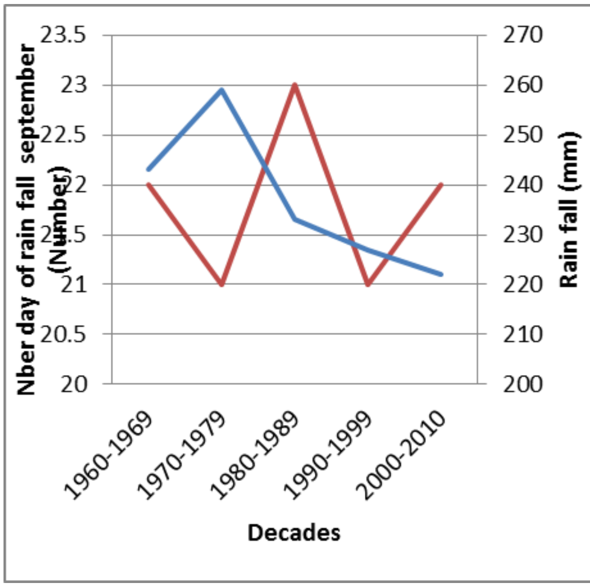
a b

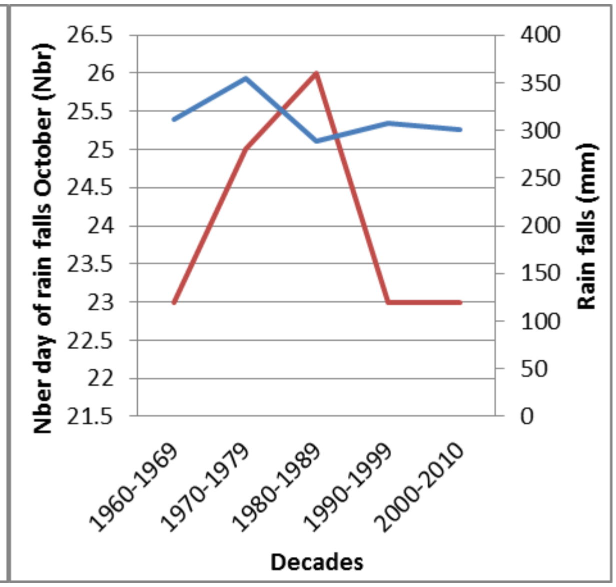
C d

Fig.4. Evolution of monthly rainfall in the south region from 1960-2010

(a) May (b) June (C) July (d) August.

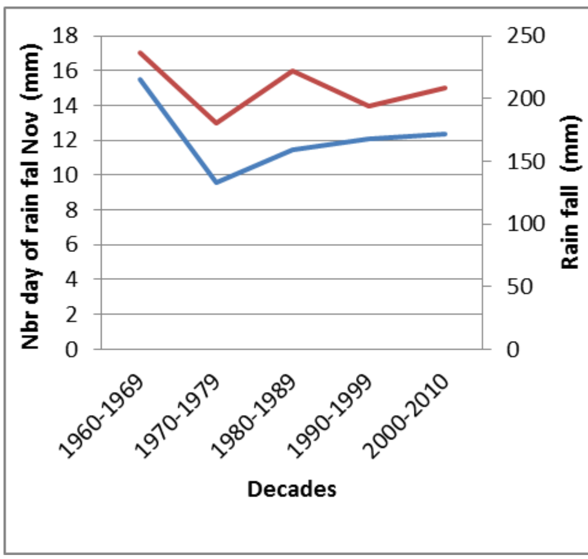
Rainfall Number days of rainfall

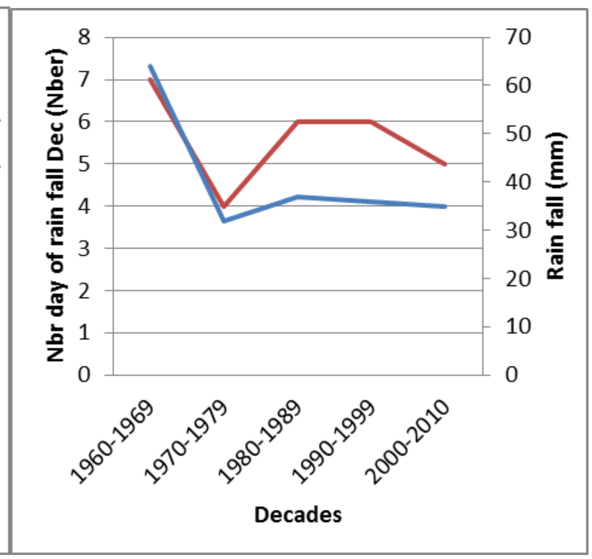




a

b





c

d

Fig.5. Evolution of monthly rainfall in the south region from 1960 to 2010 (a) September (b) October (C) November (d) December.

Rainfall Number of days of rainfall

In general, except for July and August with increase rainfall, the other 10 months of the year record an overall decrease in rainfall and the number of rainfall days (Fig 4 and 5). This is contrary to the months of June and September with a decrease in rainfall while the number of days of rainfall is gradually increasing.

III.1.1.3. Annual changes in rainfall during the dry and rainy seasons

With the exception of the short dry season with increase rainfall in the south region, the long and short rainy seasons and the long dry season shows decrease in rainfall from 1960 to 2010 (Fig 6). The long and short rainy seasons are the wettest in the south region. The short rainy season which lasts one month longer than the long rainy season records 49 mm of rainfall more than the long rainy season 718 mm**.** The evolution of rainfall in the long and short rainy seasons shows two phases within the 50 years of study. The first which is the wettest from 1960 to 1990**.** This period recorded 733 mm of rainfall for the long rainy season and 817 mm for the short rainy season. The period from 1991 to 2010 which is the driest records 795 mm of rainfall for the short rainy season and 659 mm of rainfall for the long rainy season.

The short and long dry seasons have less rainfall since they have less than 20 % of rainfall in the course of the year. The short dry season have 165 mm and the long dry season have 155 mm of rainfall. The changing trends in rainfall over the two seasons are controversial. While the short dry season is gradually increasing, the long dry season is decreasing.

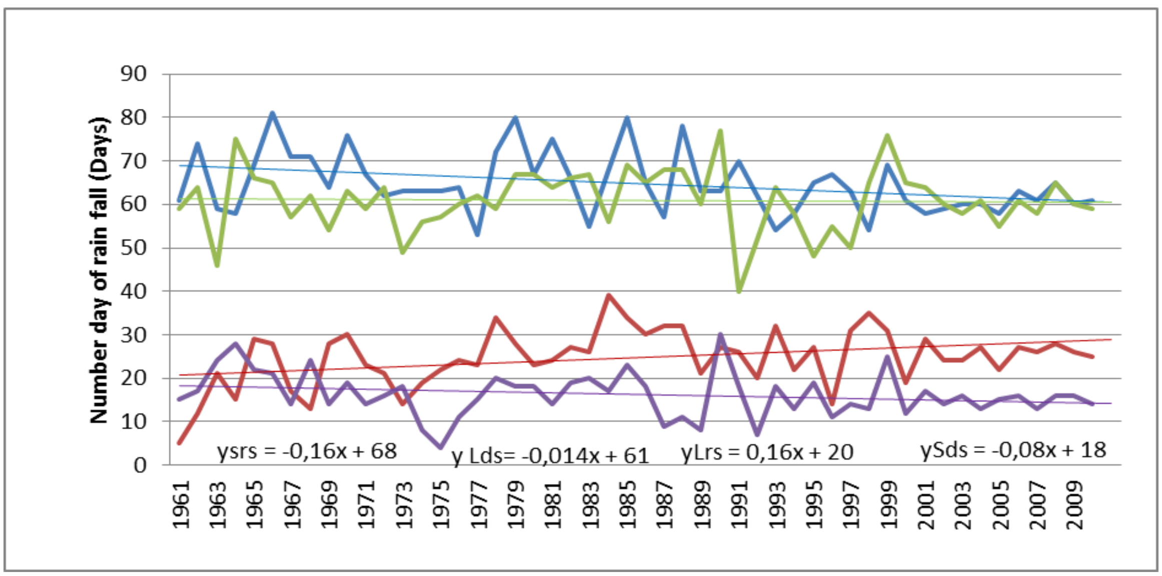


Fig.6. Evolution of annual changes in rainfall during the dry and rainy seasons.

(SRS=Small rainy season; LRS=Long rainy season, LDS=Long dry season; SDS=short dry season).

SRS LRS SDS LDS

Rainfall distribution is uneven over the study period. Only the short dry season is increasing, the long rainy season, the long dry season and short dry seasons are in constant decline over the period of study.

III.1.1.4. Evolution of the annual rainfall days during the dry and rainy seasons.

With the except of the short dry season with increase in the number of days of rainfall, the long rainy season, the short rainy season and long dry season have a permanent reduction in the number of rainfall days over the study period (Fig 7). The two rainy seasons are more spread out, with a total of 85 % rainfall days recorded during the year**.** Analyzing the trends over the study period, it is clear that the period of 1960-1990 is the widest spread for the two wettest seasons. During this period, the short rainy season which lasts for four months has an average of 43 % of the number of days of rainfall recorded in the course of the year. While, the long rainy season which lasts for three months represents 39 % of the number of days of rainfall. The period from 1991 to 2010 which is less spread simultaneously represents 61 % of the number of days of rainfall recorded during the short and long rainy seasons during the year**.**

The short and long dry seasons have less than 20 % of the number of days of rainfall recorded in the course of the year. Changing trends show an increase in rainfall in the short dry season and a decrease in the long dry season.

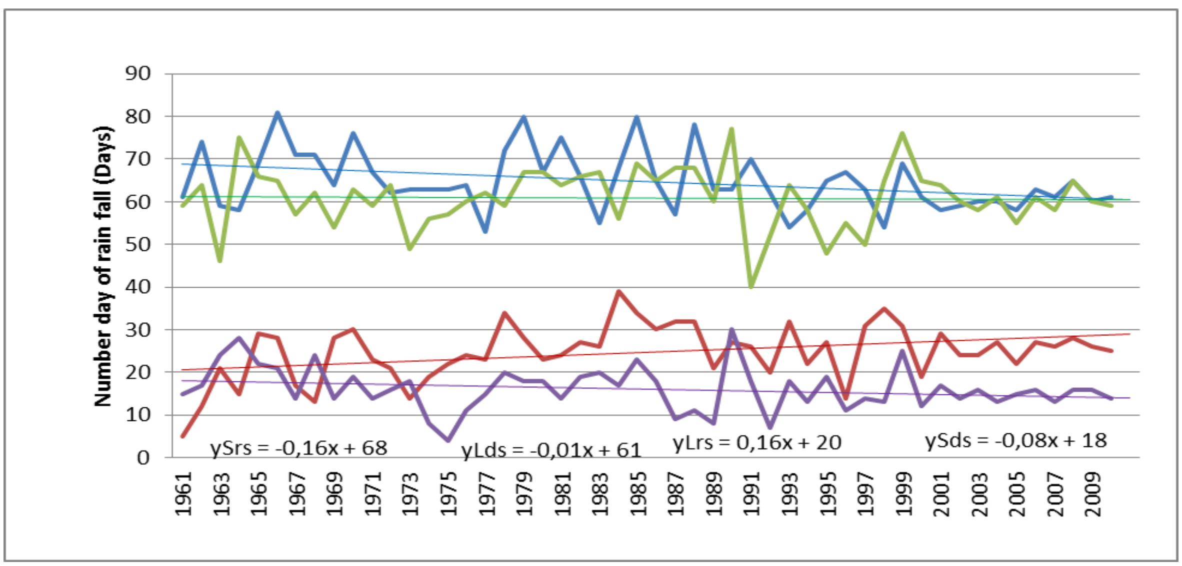


Fig.7. Seasonal distribution of the number of days of rainfall in the South region from 1960 to 2010.

SRS LRS SDS LDS

III.1.1.5. Variation from the average rainfall in the South region during the dry and rainy seasons from 1960 to 2010.

Variation from the average rainfall expresses the difference in the rainfall of a given year and rainfall calculated from the rainfall series of the study period. Figure 8a shows the deviations from the average rainfall for the short and long dry seasons, it shows that:

- 20 years of excess rainfall during the long dry season and 30 years of deficit;
- 25 years excess rainfall during the short dry season and 25 years deficit.

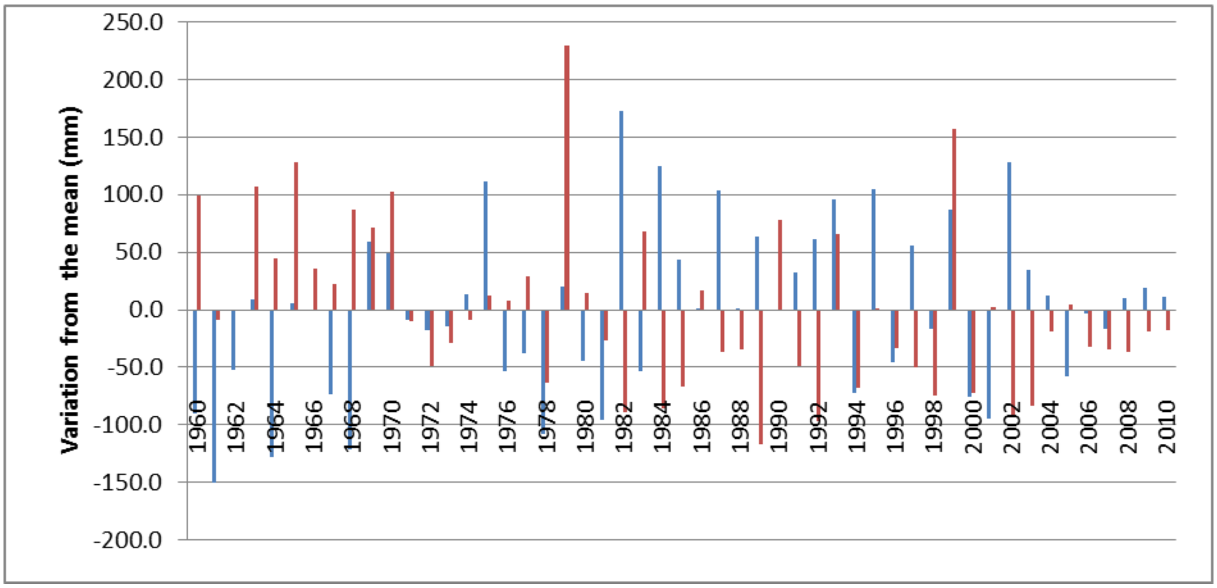


Fig 8a: Variation from the average rainfall in the South region during the dry seasons.

Short dry season long dry season

We can conclude that in each five years of the fifty years of observation, we observe 02 cases of compensation between the two long excess dry season and 03 cases of compensation between the two long deficit dry seasons. For the short dry season, a compensation case is observed in every two years between a short excess dry season and the long deficit dry season.

Figure 8b shows variation from the mean between the short and the long rainy season of the study period. We note here that:

- 23 years of excess during the long rainy season, whereas 27 years are in deficit:
- 24 years of excess during the short rainy season, whereas 26 years are in deficit

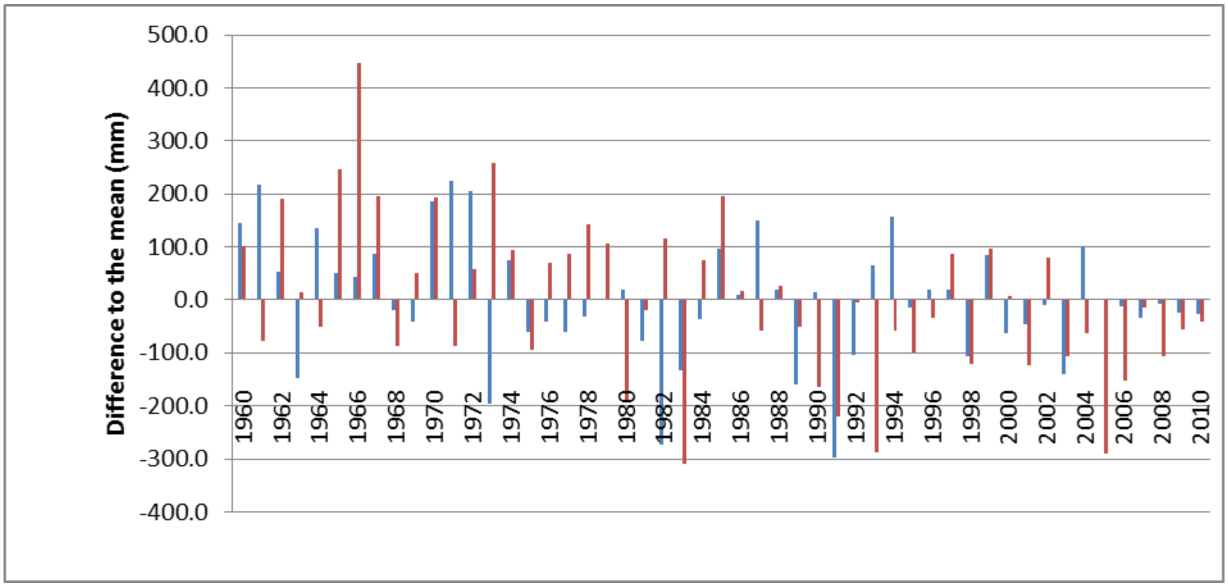


Fig. 8b: Variation from the average rainfall in the south region during rainy seasons over the study period**.**

Legend

SRS LRS

The result shows that in every five years in the fifty years of study, 2.3 cases of compensation can be observed between a long excess rainy season and 2.7 cases of compensation between the long deficit rainy seasons. For the short rainy season, in every five years, 2.4 cases of compensation are observed between the short excess rainy season and 2.6 cases of compensation between a short deficit rainy seasons.

III.1.1.6. Variation from the average number of days of rainfall in the south region during the dry and rainy seasons over the study period

Variation from the average number of days of rainfall are the annual rainfall information, that determine the difference in the number of rainfall days in a given year and the number of days of rainfall calculated on the rainfall series in the study period. Figure 7a shows that:

- 20 years of excess and 30 years of deficit in the number of days of rainfall during the e short rainy season;
- 25 years of excess and 25 years are deficit in the number of days of rainfall during the long rainy season.

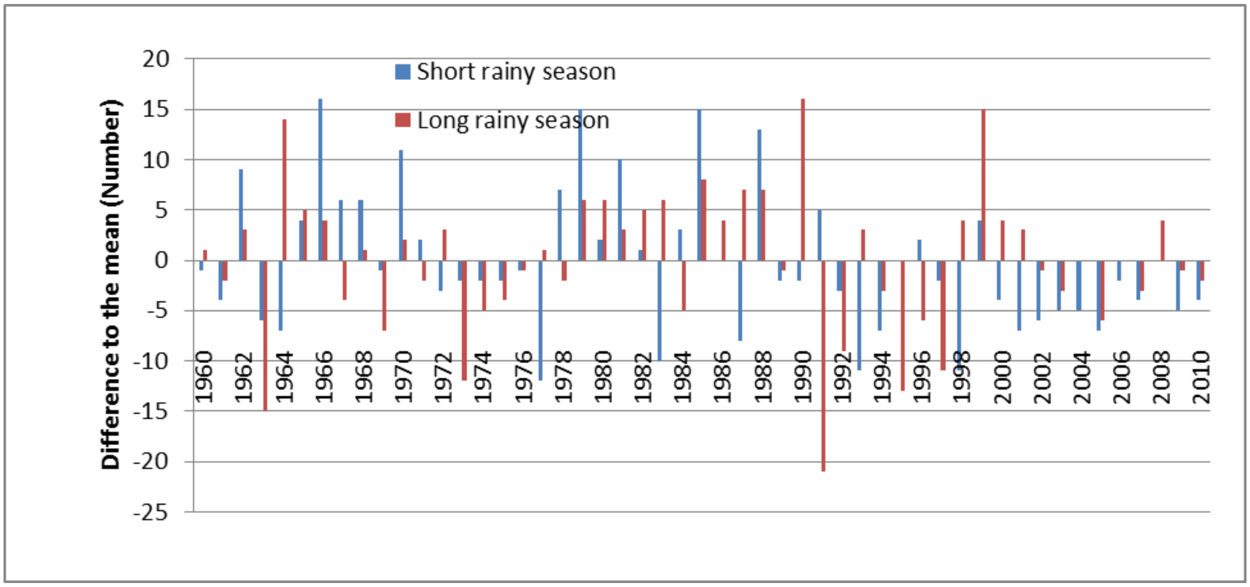


Fig.9a: Variation from the average number of days of rain fall in the south region during rainy seasons over the study period.

Short rainy season long rainy season

The evolution of the number of days of rainfall during the short and long rainy season shows that it is possible to have 02 cases in 05 a small excess number of days of rainfall and 03 cases in 05 a small deficit in the number of days of rainfall. For the long dry season, we observed in every two years a case of compensation in the number of days of rainfall between the long excess rainy season and a long deficit rainy season.

III.1.1.6. Variation from the average number of days of rainfall in the south region during the dry seasons of the study period

Figure 9b shows the evolution of the number of days of rainfall during the short and long dry seasons in the south region over the study period. It appears here that:

- 26 years of excess and 24 years of deficit during the short dry season;
- 25 years of excess and 25 years of deficit during the long dry season.

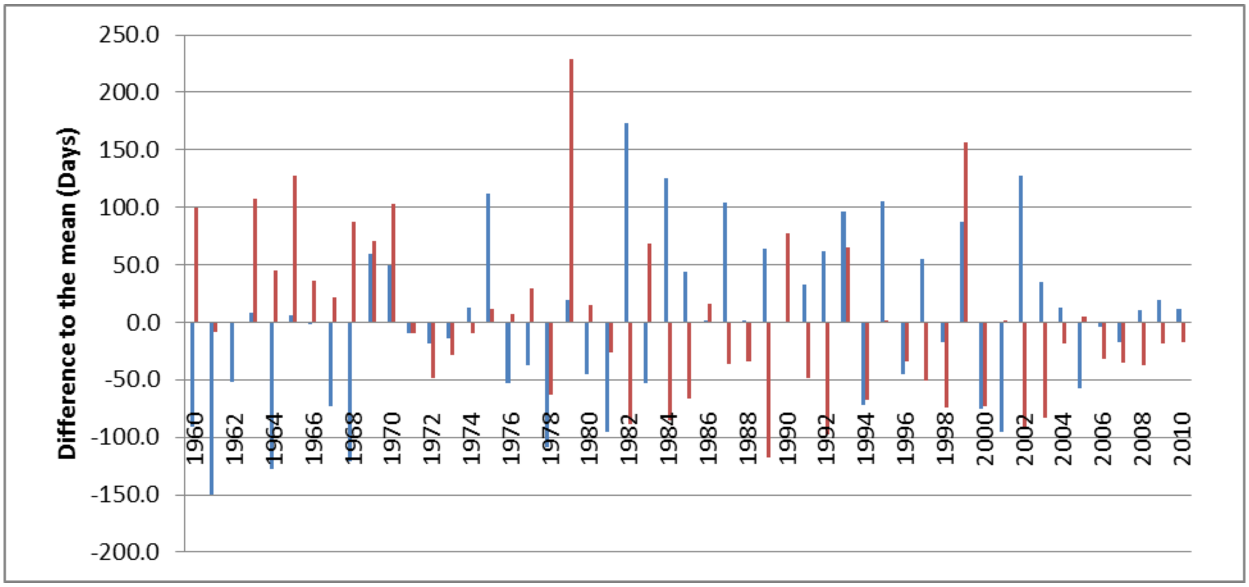


Fig.9b: Variation from the average number of days of rainfall in the south region during the dry seasons of the study period.

Legend

Following the evolution of the number of days of rainfall during the short and long dry season, its shows that it is possible to have 03 in 05 cases a small excess number of days of rainfall for the short dry season and 02 in 05 cases a small deficit in the number of days of rainfall. For the long dry season, we observed in every two years a case of compensation in the number of days of rainfall between a long excess dry season and a long deficit dry season.

III.1.1.7. Evolution of the Average annual rainfall patterns in south region over the study period.

As shown in Figure 10, there is a progressive decrease in rainfall and number of days rainfall in the south region over the study period.

It rains 1807 mm per year over 165 days on average. The year 1970, which recorded 2338 mm of rainfall, is the wettest, while the year 1991 records only 1272 mm of rainfall is the least.

Changing trends shows two distinct phases. The wettest between 1960 and 1990 with 1878 mm recording 182 mm more than the period 1991-2010 per year.
From 1960 to 2010, the wettest years are not always the most spread. The year 1985, which is spread over 206 days, recorded 2075 mm of rainfall, and the year 1992 which is the least spread with 172 days recorded 1533 mm of rainfall.

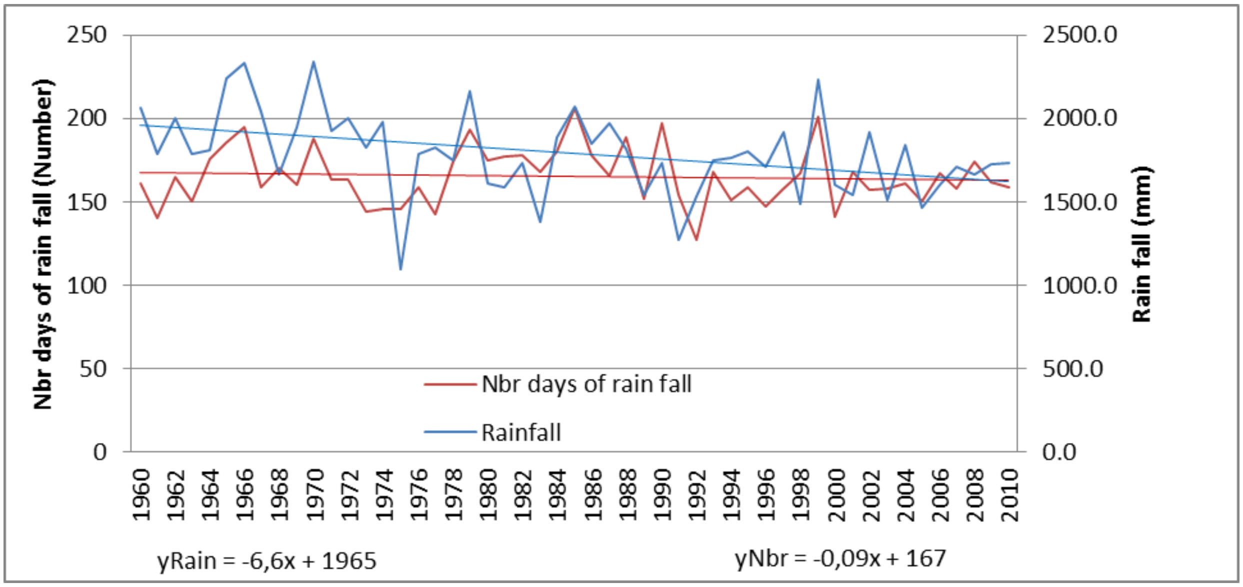


Fig.10. Average annual precipitation and number of rainfall days in the South region from 1960 to 2010.

Legend

Rainfall Number days of rainfall

In general, rainfall and number of days of rainfall decreases gradually over this 50 years study. Rainfall decreases slightly faster than the number of days of rainfall recorded. This significant difference between the two rainfall variables shows an enormous decrease in the quantity of rainfall with time**.** Such heavy rains often generate natural disasters.

III.1.1.8. Dates of the beginning and end of rainfall in the South region from 1960 to 2010

The dates of the beginning and end of the rainfall are vital information in the organization of the Djoum – Minton Congo border road activities in the south zone. The information they provide permit the organization of different activities, which are climate dependent. This information helps to avoid disruptions of activities that could be caused by unexpected or prolonged rainfall.

Figure 11 below highlights the recorded dates of the first rainfall, period of final rainfall , the quantity of rainfall between the first and the last rain and the number of rainfall days counted between the first and the last rains of the rainy period of the study zone. It appears that 96 % of the first rains collected are recorded in January and 4 % are recorded in the month of February**.** The final rainfall appears to be in December as indicated by 90 % of most cases, less than 10 % of recent rains are recorded in November of the study period.

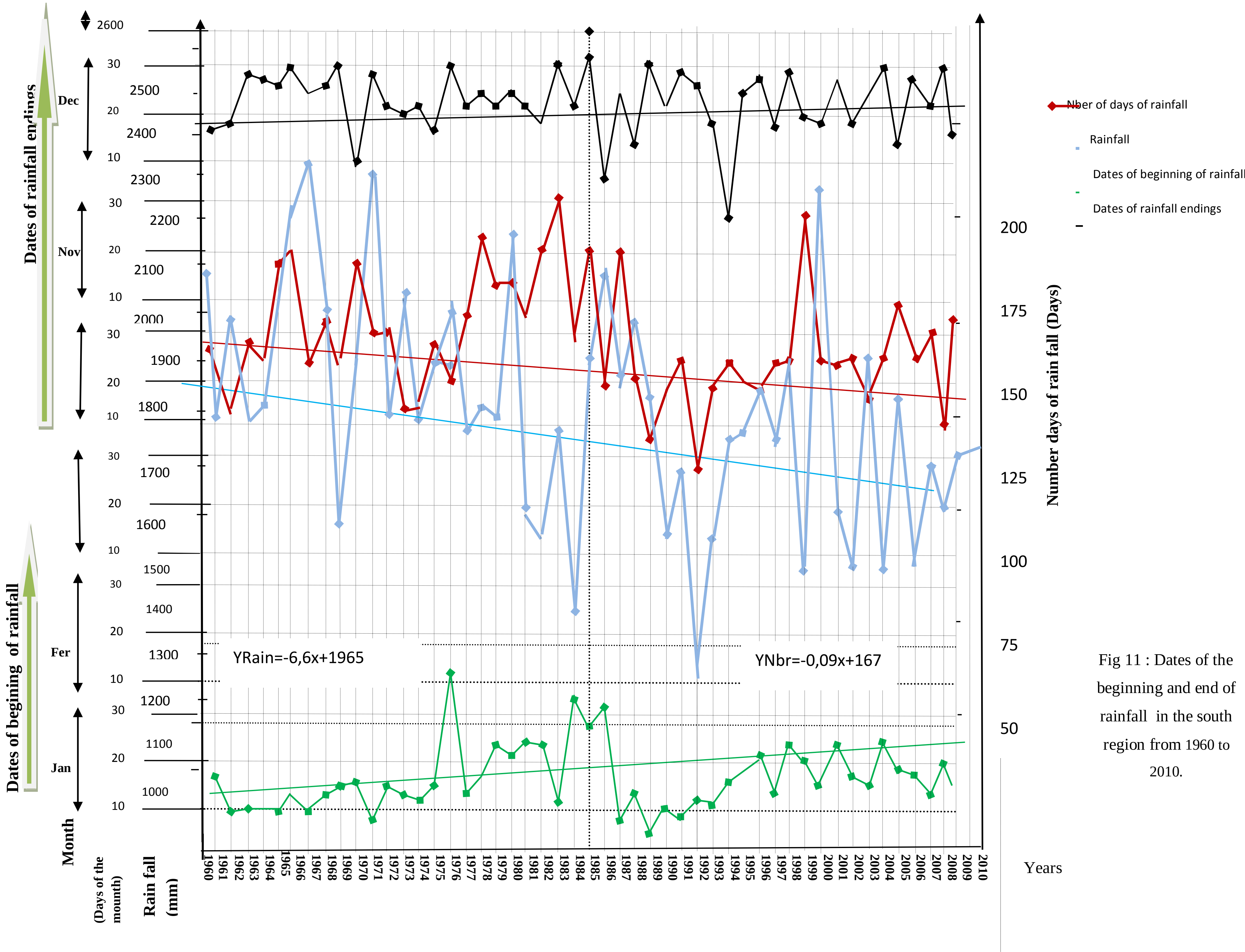


Fig 11 : Dates of the beginning and end of rainfall in the south region from 1960 to 2010.

Although rainfall in general is declining, the distribution of rainfall and number of days of rainfall is not consistent over the period of study. The beginnings of the late rains do not always correspond with the late endings of rains. As well as the beginnings the rainy season anticipated do not always correspond to the time in the south over the study period. In general, from 1975, the first rains are notice towards the end of January and the beginning of February; while the last rains are stabilize in December. Table 1 show that rain usually begins in the south region in the months of January and February and ends in the months of November and December.

The month of January that register 96 % of the beginning of rainfall, concentrates 96 % of this between the 11 and 31 days of the month, while only 4 % of the rains comes in the first 10 days of the month. The month of February receives the totality of its rain between 1stand 10thdays of the months.

Rain usually end in the month of December, which receives 90 % of the last precipitation of the year, 76 % fall between the 11 and 31 days of the month in the 50 years studied period. The remaining 24 % will arrive between 1st and 10th days of the month. The second month November receives 10 % of the last rainfall recorded. These are shared 50 % between the 21 and 31 days of the months and 25 % between 1st and 10th days of the month and 25 % between the 11 and 20 days months

Table I: Date of beginning and end of rainfall in south region from 1960 to 2010.

<table>
<tr><th>Date of start</th><th colspan="3">January</th><th colspan="3">February</th><th>Total</th></tr>
<tr><td>Percentage (Beginning of rainfall)</td><td colspan="3">96 %</td><td colspan="3">4 %</td><td rowspan="4">100 %</td></tr>
<tr><td rowspan="2">Percentage per year (Beginning of rainfall)</td><td>1-10</td><td>11-20</td><td>21-31</td><td>1-10</td><td colspan="2">10-20</td></tr>
<tr><td>51,4 %</td><td>28,5 %</td><td>21,1 %</td><td>80 %</td><td colspan="2">20 %</td></tr>
<tr><td>End of rainfall</td><td colspan="3">November</td><td colspan="3">December</td></tr>
<tr><td>Percentage (End of rainfall)</td><td colspan="3">10 %</td><td colspan="3">90 %</td><td>100 %</td></tr>
<tr><td rowspan="2">Percentage per year (End of rainfall)</td><td>11-20</td><td colspan="2">21-31</td><td>1-10</td><td>11-20</td><td>21-31</td><td rowspan="2"></td></tr>
<tr><td>25 %</td><td colspan="2">75 %</td><td>24 %</td><td>26%</td><td>50%</td></tr>
<tr><td>Number of years</td><td colspan="5">50 years</td><td colspan="2"></td></tr>
</table>

III.1.2. TYPOLOGY OF RAINFALL IN THE SOUTH REGION FROM 1960 TO 2010

Two rainfall regimes are identified in the south over the study period. We have the bimodal which is the majority and the trimordal the minority.

III.1.2.1. The bimodal regime in the south region over the study period

The bimodal regime is characterized by two dry seasons and two rainy seasons with variable length (Fig.12). The bimodal is observed during 44 years for the 50 years data studied; it represents 88 % of the identified regime. The maximum height of rainfall is between September and October. The total annual rainfall is 1807 mm on average. The short dry season last for 02 months; July-August, while the long dry season that lasts for 03 months runs from December to February. The short rainy season lasts for 04 months from March to June, while the long rainy season runs from September to November 03 months.

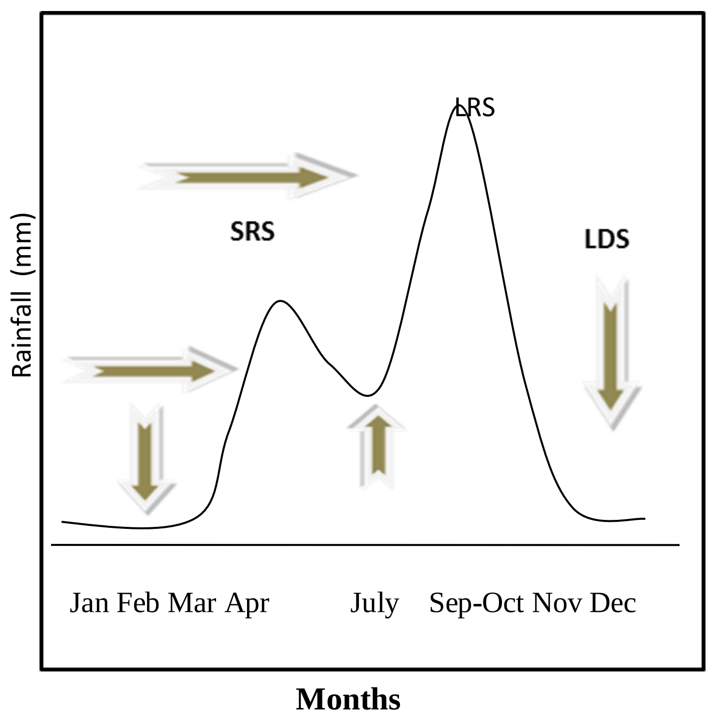


Fig 12: The bimodal regime in the south region during the study period

III.1.2.2. The trimodal system in the south region

The trimodal system is characterized by three rainy seasons and three dry seasons with variable lengths (Fig 13). The maximum rainfall usually occurs between the months of September and October. The total annual rainfall is 1829 mm of rainfall, with the short dry season and the short rainy seasons that last for 01 to 02 months each. The long dry season which runs between the months of November and February last between 03 and 04 months, while the long rainy season which runs from September to the month of October last for 03 months.

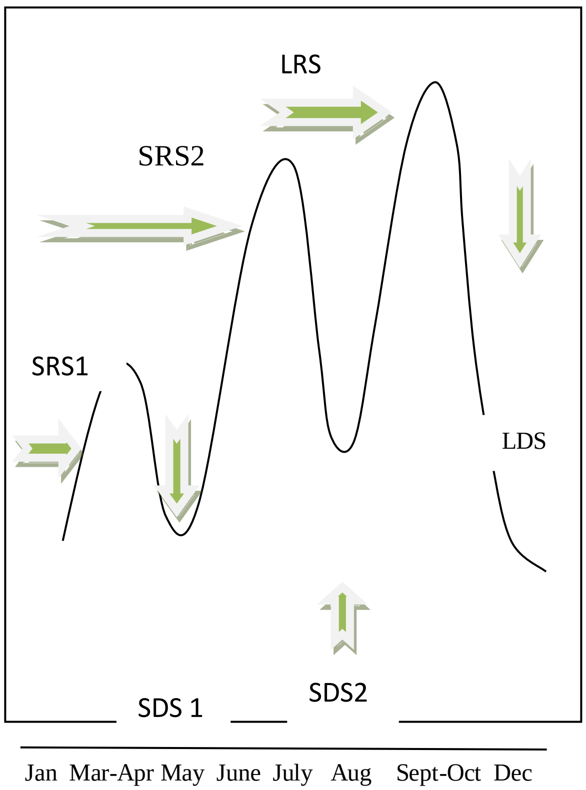


Fig.13.The trimodal regime in the Ebolowa in the study period.

SRS: Short rainy season SDS: Short dry season LRS: Long rainy season LDS: Long dry season

III.1.2.3. Regime distribution observed in the south region

The distribution of rainfall patterns observed in south region (Table II) shows that the majority is the bimodal with 88%, followed by tri-modal system that represent only 12% of the identified regime

Table. II. Proportion of years by regime observed in the south region from 1960 to 2010.

Régimes	**Bimodal**	**Trimodal**	**Total**
Parentages	88%	12%	100%
Years	45	06	51

III.1.2.4. Changes in precipitation regimes in the bimodal and trimodal regime in the south region from 1960 to 2010

III.1.2.4.1. Changes in precipitation in the bimodal regime in the south region over the study period.

The bimodal regime is specific to the south region over the study period (Fig12). The average annual rainfall is 1807 mm distributed within the four seasons, thus two dry and two rainy seasons with variable durations. Rainfall distribution is uneven in the 04 seasons of the year.

In general, the short rainy season last for 03 to 04 months and records 42.3% of the total annual rainfall. While the long rainy season that do not exceed 03 months has only 40% of the annual precipitation. The distribution of rainfall during the years presents an overlap between the two rainy seasons. The years 1961, 1964, 1971, 1980, 1983, 1987, 1990, 1983, 1987, 1990, 1994, 2002, 2003, 2005, 2006 and 2008 present a long rainy season more rainy than short rainy season. The years 1962, 1965, 1966, 1967, 1969, 1970, 1973, 1974, 1975, 1976, 1977, 1978, 1980, 1981, 1982, 1984 on the contrary present a short rainy season more rain than the long rainy season.

Just as the rainy seasons, the two dry seasons also shows an overlap. The years 1973, 1975, 1982, 1984, 1986, 1987, 1988, 1989, 1991, 1992, 1993, 1995, 1996, 1997, 1999, 2000, 2003, 2004, 2008, 2009 and 2010 have a short dry season rainier then the long dry season. while the years 1961, 1962, 1963, 1964, 1965, 1966, 1967, 1968, 1969, 1970, 1977, 1978, 1979, 1980, 1983, 1990 and 2005 have a long dry season more rainier than the short dry season.

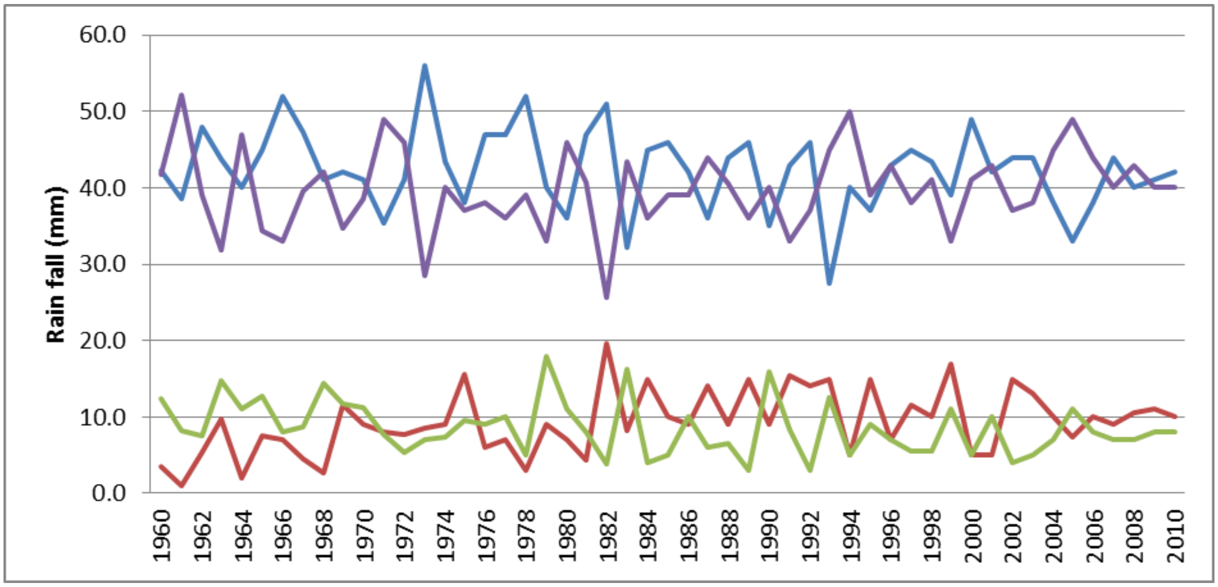


Fig.14: Distribution by season rainfall in the bimodal regime in the south region over the study period.

III.1.2.4.2. Annual changes in rainfall in the trimodal regime in the south region from 1960 to 2010

The trimodal system is observable in 06 years as shown in Figures 15a and b. It has 06 seasons thus, three wet and three dry seasons, with varying durations. Figure 15a shows the evolution of the trimodal rainfall regime in the years 1965, 1975 and 1980.Over these years we observed a steady regular displacement of the different seasons within the year. The short dry seasons varies between the months of April, June and August, while the short rainy seasons occurs respectively in the periods of January to March, May-June and July. The long dry season is permanent between the months of November to February, while the long rainy season is observed between September and November.

The Figure 13b shows the evolution of rainfall in the trimodal system in the south region in 1982, 1988 and 1995. In the first three years, the dry and rainy seasons remains unstable during the year. The Short dry seasons are constantly being displaced between the months of April, May, July and August during the year. The short rainy seasons on the contrary varies between the periods of February-March, May-June, and August-September. The long dry season on the contrary is displacing between the months of November and February, while the long rainy season differs between August and November.

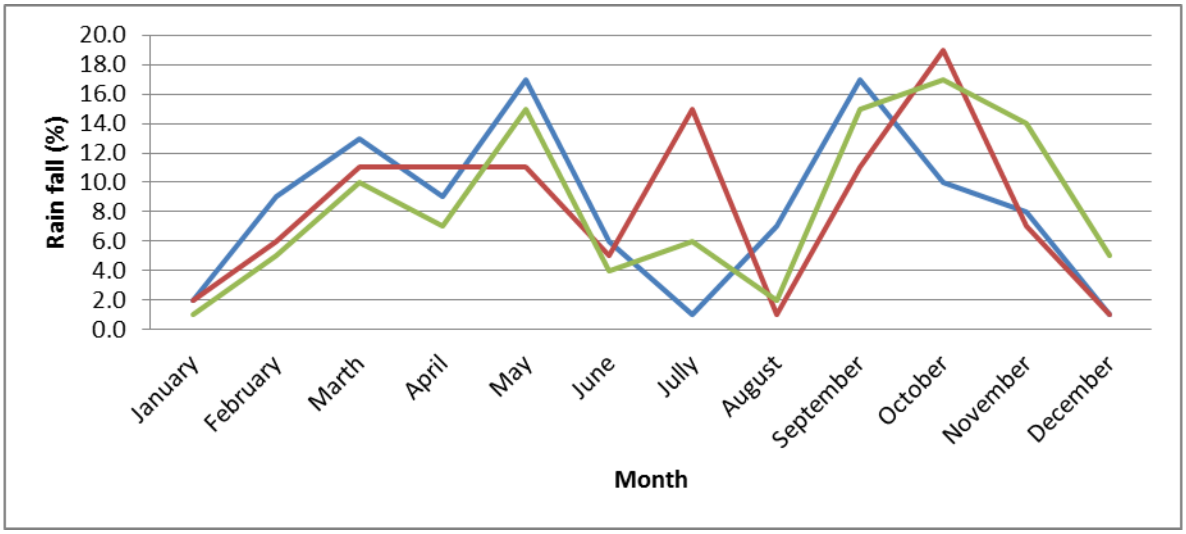


Fig.15a. Distribution of rainfall in the trimodal climate regime in 1965, 1975, and 1980

1965 1975 1980

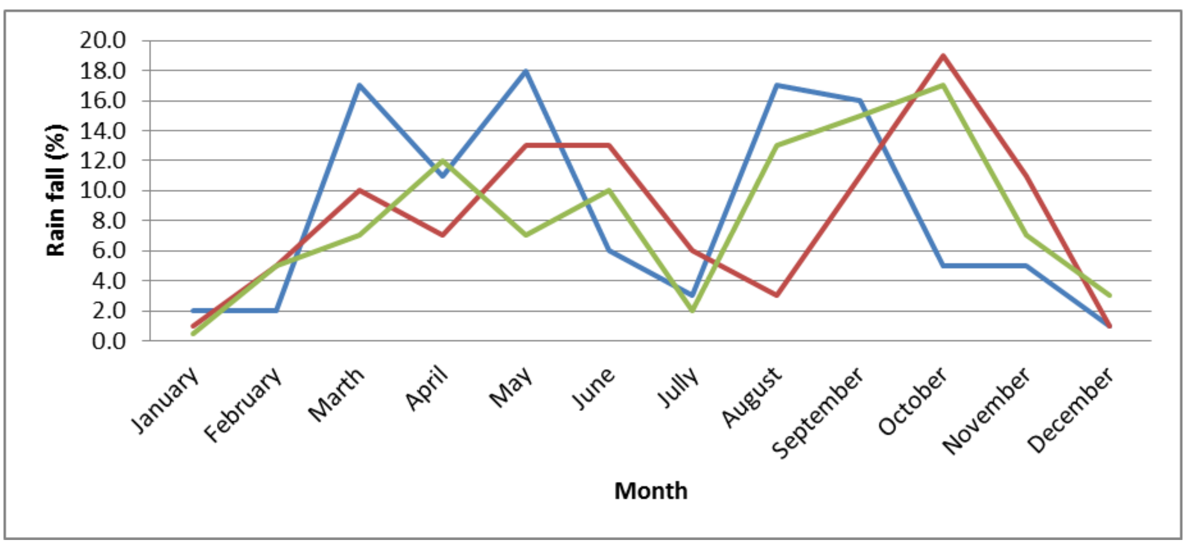


Fig.15b. Distribution of season in the trimodal regime in 1982, 1988, and 1995

1982 1988 1995

III.1.3. EVALUATION OF THE DJOUM-MINTOM CONGO BORDER ROAD (NRN: 9) CONSTRUCTION ACTIVITIES AND HOW THEY CAN BE INFLUENCE BY CLIMATE

The Djoum - Mintom Congo border road construction begins with a preliminary study of Djoum -Mintom road track which is the first phase of the project. This study is done by qualified study group selected by the government (National invitation to tender) .At the end of this studies data were given to the government on the total volume of work to be done i.e. the cumulative length of bridges and culvert to be constructed. The overall estimate of swamps to be treated and the volume of earth work to be done. It was estimated that a total of 43,400,000 m^3 of soil has to be excavated thus 16,800,000 million meter cube of soil a year and 1.400000 m^3 per month. After these studies the slope of the road is formulated, as well as the geotechnical properties (soil moisture content, thickness of each layer) to be applied on the road. This road is expected to last for 15 years thus a thickness of 300 gr/cm^2 of residual gravel and 5 cm bitumen is required. A maximum liquid limit of 20 % and a plasticity index of 30 % for foundation soil. Soil excavation makes about 80 % of the road work. The equipment used are standard equipment in the public work sector .They ranges from tractor grader, caterpillar bulldozers etc.

Soil excavation is defined as the removal of materials (soil or rock) from one point to another and can be classify as:

- roadway excavation ;
- drainage or structure excavation;
- borrow pit excavation.

III.1.3.1 .General soil excavation.

This involves the general earth work that prepares the road platform for the other subsequent layers and drainage excavation. Road way excavation includes bush clearing, soil stripping, cut and fill, and removal of purge. Drainage excavation involves the digging of channels beside the main road pavement for erosion control

III.1.3.1.1. Bush clearing

This is the overall cleaning up of the area where the road passes. It has a width of 15 to 20 m to ease visibility. Its involves the cutting down of trees with the use of a bulldozer.

III.1.3.1.2. Soil stripping

This involves the removal of the top soil 30 cm after bush clearing. Top soil is vegetative soil which is subjected to decay and if included in the road foundation soil it might produce holes which will cause road degradation at an early stage.

III.1.3.1.3. Removal of purge

The surface material attended at platform level after cutting might be subjected to substitution when judge not suitable by geotechniciens. In this case the soil is removed 30 cm to 1 m depending on the state of the material and then replace by a suitable soil.

III.1.3.1.4. Cutting and filling

Cut and fill is a procedure in road construction side to level slopes and create drainage channels and embankments by removing earth from one points (Cut) and using it as a filling material in another point. It makes up about 70 % of the general road construction process. in cutting, soil is cut off from higher elevations to attend the platform level. While in filling soil is deposited in area of lower elevation to attend the platform level .The materials from cutting are used for filling when judge technically suitable by the geotechiciens. In cases where these materials are not suitable such as clay they are send to soil depot created some few meters away from the construction site. Materials used for foundation are mostly laterite from burrow pit. They have coarse grain particles and increase the drainage system of the road.

A B C

Fig.16. A. Cutting to reduce surface B. Filling to increase surface C. Soil tripping to remove vegetative top soil.

III.1.3.1.5. Climate influence on soil excavation in Djoum - Mintom Congo border road.

With rain fall of the 5mm to10 mm the preliminary road activities (soil excavation) cannot be carried out, because of the saturated condition of the soil (Fig 17). These early construction activities bush clearing, soil stripping, compaction, drainage site excavation, cut and throw, embankment (surfacing) are highly subject to the climatic conditions (rainfall and temperature) of the ZP. This is because with rainfall, the soil becomes saturated and muddy and cannot be work on. This will require significant remedial work of erosion and sediment control. Also time will be needed for the soil to dry up, before work can resume. The density of the soil depends on the moisture content and they is an optimum moisture content to obtain the maximum soil compaction. As recommended in the (Cahier des clauses techniques particulars) (CCTP) of the project. The soil to be used for embankment most have a plasticity index of 30 g/cm^3 or liquid limit of less than 20 g/cm^3. In case of dry soil, water can be added with the help of water sprinklers, but in case of muddy soil the only option is to dry the soil to this optimum level with the help of the sun. This process of drying is what causes delay because most often depending on the degree of saturation, a good numbers of days is required depending also on the intensity of the sun .Also with intensive soil saturation movement of the heavy engines are impossible and they is delay in the transportation of materials from one village to another.

A **B**

Fig. 17. A: Road pavement saturated with water after rainfall B: Culvert saturated with water.

III.1.3.2. Rock crushing, hot mix preparation and concreting.

This takes place in the quarry where all the various components (gravels) to be used in the preparation of the hot mix (concrete) for the foundation and bitumen are prepared. A rock crusher helps to crush larger rock fragments into aggregate of various sizes ranging from the 0 -4, to 4-6, and 6-10, mm grain sizes. These aggregate are then separated by meshes of different size spacing to different component for deposition. The finest size particle 0-4 (sand) is the most important ingredient in the hot mixture formulae, taken 60 percent.

Hot mix (tar) is a mixture of the various size particles of 0-4, 4-6, 6-10 mm with organic peat (asphalt) at a temperature of 120 to 160 ^{o}C, with the help of an asphalt plan.

Road pavement with asphalt involved a series of layering process from liquid asphalt application to the hot mix which is the final stage in road paving. This is done with the help of an asphalts plan.

III.1. 3.2.1.Climate influence on rock crushing, hot mix, (bitumen) and concreting.

With rainfall the finest size particles collide with the large once and blocks the mesh and thus segregation with the other courser gain particles is impossible. Thus with rainfall above 5 mm rock crushing is impossible.

More over rain will increase the water – cement ratio during concrete mixing and this will lead to the development of early cracks (Fig 17). Newly laid concrete will be destroyed and labour will not be fully utilized.

After the final set, rain can induce rapid cooling at the surface, leading to rapid development of thermal restraint stresses and possibly early-age uncontrolled cracking.

The design of the asphalt is in function with the temperature of the zone. Asphalt application takes place at a temperature of 130 to 150 ^{o}C .Temperature below or above this will reduce the strength of the asphalt. Also its application cannot be done when ground temperature is less than 2 ^{o}C. This will lead to the rapid cooling of the asphalt and thus the formation of early cracks.

Fig .18. Road base course with gravel of different grain sizes

III.1.3.3. Other factors influencing the Djoum- Mintom Congo border road project other than climate

They are many other factors affecting this road project; they ranges from luck of fuel and experts, vehicles breaking down, and non-respect of work schedule. It's important to note that this road project has not been suspended since its beginning in 2011 because of budgets.

III.1.3.4. Level of understanding of climate variation and its influence on road work.

The use of questionnaires gave an idea of the level of awareness of climate variation in the south and its influence on road work among civil engineers in this project and the indigenous people. The result obtained shows that 60 % of the workers are aware of climate variation manifested in the form of increase in temperature, prolonged rainy season and rainfall out of season (Fig.19). For the indigenous people climate variation is experience due to their inability to determine the various planting seasons in the region. Thus extreme temperature, out of seasonal rainfall and the changes in the beginning of seasons each year. The inquiry on climate and road was analyzed on 100 % for each of the question presented. From Figure 20; It can be seen that 85.5 %, were for the fact that too much rain will interfere with soil excavation (SE), 50 % for extreme weather delay transportation and delivery of materials (EWDTD), 80 % for extreme weather affects health and safety of workers (HSW), 76.5 % for extreme weather affects dates line of project delivery (DLPD) 89 % for weather reduces the income of the enterprise (RIE) while 40 % for non-climatic factors (NCF) like vehicles break down, luck of fuel, and incompetent workers delays the construction the Djoum - Mintom Congo border road work.

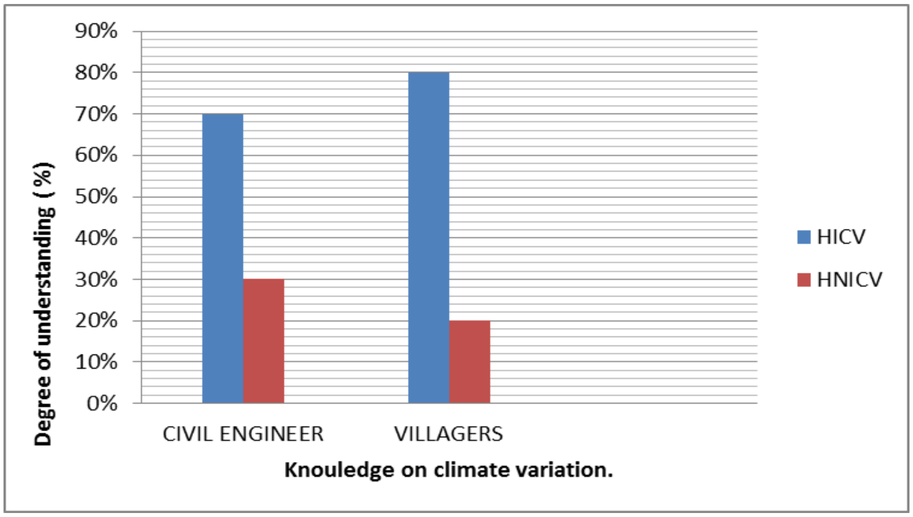
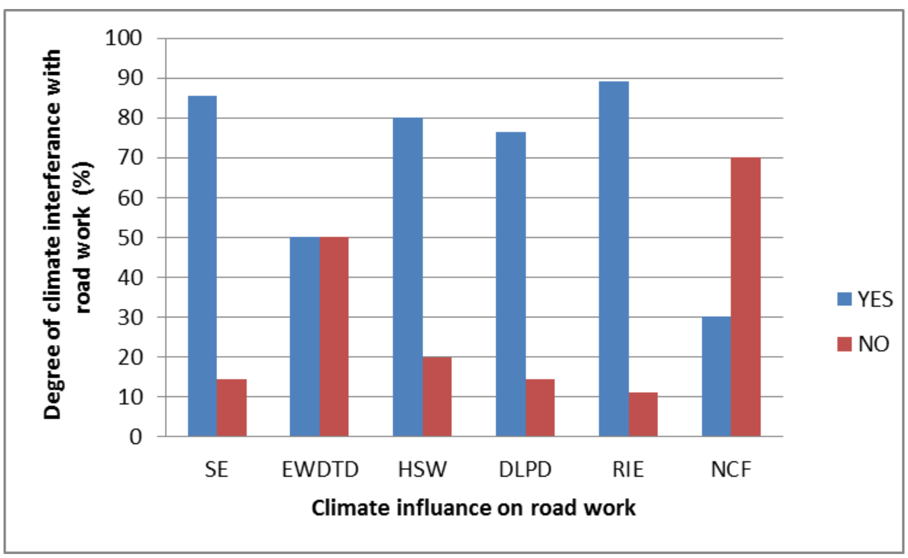


Fig.19. Knowledge of understanding of climate variation in the south region.

HICV: Have idea on CV HNICV: Have no idea on CV



Yes NO

Fig 20. Knowledge of understanding of climate influence on road work.

III.1.3.5. MONTHLY EVALUTION OF THE DIFFERENT ACTIVITIES IN ROAD CONSTRUCTION

The tables below show the monthly evolution of the different activities road construction work, from 2012 to 2013. Data for 2013 ends in September which is when this research ended. Data from the Ebolowa station will be used to programme the different activities in road work. Because of the incomplete nature of the 2013 data, emphasis will be lead on the 2012 data which gives the actual evaluation of the work done each season and within the year.

Table III. Monthly work evaluation in 2012

Month	Bush clearing	Soil stripping	Cut to throw	Cut to fill	Drainage	Filling from borrow	Removal of purge	Total	Percentage
Jan	15680	16861	15400	19850	19601	16400	16400	120192	60.4
FER	19200	19386	12905	15600	15257	16611	14041	121200	58.1
MAR	9350	10401	11021	10623	9984	10452	9201	71000	35.5
APRI	5464	8100	7223	6501	8604	9290	8201	46000	23
MAY	8061	6461	4501	5402	6201	6522	4500	38600	19.3
JUIN	5421	5121	45202	5204	4348	16031	7051	63600	31.8
JULY	16661	19488	21600	19461	17943	25943	19432	141000	70.5
AUG	11000	11707	12023	13934	15362	13893	11023	80000	40
SEPT	5602	7051	7083	9300	7023	7031	9200	40000	20
OCT	3466	6301	4300	4250	5450	4000	2301	27000	13.5
NOV	15960	12164	19637	13903	14573	10782	14647	101600	50.8
DEC	21485	16944	26944	15948	20000	19843	15783	136947	65
TOTAL	167748	181478	183939	170076	147746	219088	164980	1240701	487.9

From an estimation of 200000 m^3 of earth work for each of the different activities, it can be seen that they is no month with a complete 200000 m^3 or 100 % work done .However the dry months December, January, February, July and August shows the highest work done. The wet months shows the least with September and October haven the lowest.

Table IV: Evaluation of work done per month in 2013

Month	Bush clearing	Soil stripping	Cut to throw	Cut to fill	Removal of swamps	Filling from borrow	Removal of purge	Percentage
JAN	17802	13840	10382	9650	17031	15851	13348	55.7
FER	14650	15961	16424	18460	2561	22561	12435	57.7
MAR	7300	9450	10350	9346	14991	14991	6015	39.2
APRI	5300	4881	6400	5451	9358	9358	3248	20
MAY	5020	3481	8300	7891	9900	9900	4078	15.3
JUIN	11450	15852	11491	10951	12648	14648	13851	32.4
JULY	16750	18451	16881	13891	18348	18348	14351	65.68
AUG	10020	11951	9810	9800	14500	12500	14981	402
SEPT	9500	10051	10783	12300	10023	13031	9200	25.4

III.1.4. CORRELATION BETWEEN CLIMATE AND THE DJOUM-MINTOM CONGO BORDER ROAD DEVELOPMENT ACTIVITIES FROM 2012 TO 2013

III.1.4.1.Correlation of monthly rainfall, number of days of rainfall and percentage of monthly work done

A correlation of work done per season brings out the quantity of work done with respect to the average rainfall and number of days of rainfall per season.

Table V: Correlation between mean rainfall, number of days of rainfall and work done per month

Month	Mean rainfall	Nber of days of rainfall	% Activity
January	40	4	60.6

February	80	7	58.6
March	17.5	13	35.5
April	210	17	23
May	210	18	19.3
Juin	160	13	31.8
July	70	5	70.5
August	100	7	40
September	225	17	20
October	375	23	13.5
November	170	14	50.8
December	25	5	65.5

The table shows that work is efficient during the months of December, January, February and July with low rainfall and number of days of rainfall. October and September have the lowest percentage 13.5 and 20 % respectively with corresponding increase in rainfall and number days of rainfall.

III.1.4.2. Correlation of Seasons, number of days of rainfall and work done

Table VI. Correlation between seasons, number of days of rainfall and work done.

Seasons	Average rainfall	Average number of days of rainfall	% Activity	Number of months
Short dry season	165	22	16.9	1.5
Long dry season	155	17	43.2	3
Short rainy season	795	70	20	4
Long rainy season	644	66	19.5	4

The tables above shows that road work is best done in the dry season then in the rainy season. The two dry seasons have the highest percentage 16.9 and 43.2 % for the short and long dry season respectively while the two rainy seasons have 20 % and 19.5 % work done for the two seasons. It is important to note here that the dry season have 5 month as against eight months for the rainy season. Although the dry period have a higher percentage of work done it's not as presume by the enterprise because of unpredicted rainfall.

III.1.4.3. Road adaptation to climate variation

Changes in climate variables will have a substantial effect on the general hydrology including those beside the road, which will influence the amount of runoff reaching the road. The NRN:9 drainage channel have been adapted to climate variation by increasing the height of bridges and culvert, taking in to consideration the highest flow rate ever recorded in each flowing steam. Also these structures are painted with bitumen to reduce their contact with water. For the foundation a thickness of 50 cm of gravel laterite, with a concrete layer of 300 cm^2 of bitumen residue and a final layer of 5 cm bitumen as specify in the CCTP of the project. This is to adapt the road to heavy engines that transport timber from Congo and the forest in the region to the Douala port. The road is assume to have a life span of 15 years

III.2.DISCUSION

A look at the climatic trend in the south region shows that they is rapid climate variation which is signs of climate change. This in line with Ayoughe (2001) and Molue (1999) who carried out similar studies on climate in Cameroon and concluded that they is variation of season and a decrease in rainfall and number of days of rainfall. But the decrease in rainfall is more rapid than that of number of days of rain. The distribution of these seasons and the number of days of rainfall are not regular over the study period.

They are constant displacement of seasons as seen in the trimodal regime. The beginnings of late rains do not always coincide with the late endings of rain, as well as the anticipated rainfalls do not always correspond to that collected. Also field investigation shows that the wet periods are accompanied by high temperature days as well as the dry period with rainy days. This in line with Beauvilain (1985) and peel, (1966), who carried out studies on climate in the north of Cameroon and concluded that extreme dry and wet period turn to cluster together, making it difficult to determine the beginning and end of each season. Beside the displacement of seasons, they are the phenomenon of seasonal compensation where a deficit in rainfall in a season is being compensated for in the preceding season. This phenomenon can be used to predict the next season thought it’s a matter of probability and can only be done within a year. This however is very frequent in the dry seasons.

From Investigation made with the civil engineers and from field observation its understood that rainfall effects varies with the nature of road work, but the most sensitive is soil excavation which is about 70 % of road work. Heavy rain lead to complete suspension of road work since it affects the working condition of the soil and the health of outdoor workers. This in conformity with Poncelat (1958) who carried out similar studies in Belgium that with rainfall of 5 to 10 mm road construction is impossible and with Anonymous (2010) that rainfall affects the health of road workers especially those working outdoors. Also asphalt application cannot be done when ground temperature is below 2 ^{o}C. This will lead to the rapid cooling of asphalt and thus the formation of early cracks. This correlate with the study carried out by Willyway (2003) in . This however will cost the enterprise millions if not plan for in advance. Soil excavation is efficient during the dry season December, January, February, July, and August have the highest work done with an average rainfall of average 80 mm. less work is done in the month of April, May, September and October which are the peck of rainy season in the south region. This difference is because in the dry seasons the numbers of days of rainfall are less than that of the rainy season. Moreover they are enough sun during the dry seasons to dry the soil then in the rainy season. This is a very important aspect in civil engineering work especially in Africa where erosion controls during construction are not practice.

CHAPTER IV. CONCLUSION, RECOMMANDATION AND PERSPECTIVES

IV.1. CONCLUSION

The south region like most regions in Cameroon shows a constant variation of seasons with two climate regime alternating year after year. Generally the region has four seasons. From field observation the rainy seasons are interwoven with high temperature days as well as the dry seasons are accompanied with rainfall. Such variations are in line with the projected climate of the country with 1.5 ^{O}C to 4.5 ^{O}C increase in temperature, sea level rise in coastal areas and flooding by 2100 in most part of the country.

The road sector is highly sensitive to extreme weather conditions since the main element for construction, the soil, is subjected to the various climatic elements irrespective of the environment. Road activities are best done in the dry season since in most cases an extremely dry soil can be water with sprinklers to achieve a plasticity index of 20 % and does obtain maximum compaction. But with rainfall the only solution is to suspend work until the soil can be dried up by the sun. This will delay the time of project execution and subsequently lead to increase in the project budget. The most difficult problem forcing the construction company MNO VERVAT Cameroon are unpredicted rainfalls. This is because with accurate seasonal predictions workers can be send on leave. This happen in the month of October 2012, where workers were send on leave because of heavy rain in September but unfortunately October turnout to be a dry month. Thus in line with Molue (1999), humanity cannot accurately predict with certainty what the next season will bring. This is something the government and civil engineers would like to know because it's important in their decision making.

IV.2. RECOMMANDATION

It's important for the road construction enterprise MNO VERVAT Cameroon to study the present climatic regime of the south region. This in conformity with Anonymous (2010) who carried a similar research in Nigeria will give a better understanding of the seasonal trends expected within the project zone. Most soil excavation activities can be programmed in the dry season which is expected to start in December to February for the long dry season and from July to mid-August for the short dry season. The rainy seasons which are wide spread (seven months) can be well managed. During the rainy season rainfall is not intense at the beginning and towards the end (March, and July), for the long rainy season, (August and November) for the short rainy season. Thus soil excavation work can be programmed during these months while the rest of the months with intense rainfall can be concentrate on road base layering. The latter is done with gravels of different grain sizes and has little or no rainfall influence.

The enterprises have to respect it work schedule as confirmed by Clayton (1989) who carried out similar studies on road construction in Nigeria, always taken in to consideration the unpredictable nature of the climate. Haven in mind that weather is a dependable factor in most of its activities; it's advisable to deal with all other factors that can delay project execution.

The south region normally describe as a dense forest zone suffers from forest degradation by many logging companies concentrated in the region. This forest heavily exploited is not replanted thus the major sink of CO_2 the main GHS is constantly being destroyed. The road sector its self is already partaking in the destruction of the forest. Afforestation should be done when the work is completed.

In order to improve road quality, the climate must be taken in to consideration, and civil engineers have to increase their knowledge on climate for better adaptation of road infrastructures. This is very important, considering the budget involve in this sector and it's important in the development of the country's economy. Thus Civil engineers and government policy makers must work together to anticipate and plan for these impacts. This is in line with the European Commission Green paper 2007 on climate adaptation, which start that it's cheaper and better to start climate change adaptation than to face the consequences in the future.

Addressing climate change requires two types of response. Firstly, and importantly, we must reduce our greenhouse gas emissions (GHG) (i.e. take mitigation action) and secondly we must take adaptation action to deal with the unavoidable impacts.

Therefore, governments and policy-makers have a responsibility to understand these climate change impacts and to develop and implement policies that will ensure an optimal level of adaptation on the road network as well as the humanity. .

IV.3 PERPECTIVES

With the possibility of continuing this research more will be done on both temperature and rainfall, this will bring out the actual variation of this two climate variables in the region.

Also little attention have been given on how current road structures can be adapted to the present climatic trends, this is an important aspect that has to be considered in subsequent studies.

As specify by Mills B.et al, (2009) it's important for drainage and ditches to be constructed base on flow rate calculation using rainfall intensity for at least 50 years and also with climate change correction.

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ANNEXES

QUESTIONNAIRE FOR THE EVALUATION OF CLIMATE VARIABILITY I N THE SOUTH REGION OF CAMEROON AND ITS INFLUANCE ON THE DJOUM - MINTOM CONGO BORDER ROAD PROJECT .

GENERALITY.

NAME____

Highest qualification ____

I- PERSONAL OBSERVATION

1. Since when do you exercise in this structure____________________________

2. Do you think climate change is real

a) Yes ☐ No ☐ don't know ☐

b) If yes, how do you experience this changes.

- Increase temperature ☐ -Increase rainfall☐Decrease rainfall -- ☐

Prolong seasons ☐

3. Do you think climate variability can be ameliorated through coping mechanism?

- Yes ☐ No ☐
- If yes, how ?

Reducing deforestation ☐ Proper discharge of industrial and household waste ☐

II- CLIMATE AND ROAD ACTIVITIES

4. Does this climate change affect road construction activities :

a) Yes ☐ No ☐ Do not know. ☐

b) if yes, What are the climate variables that influence road construction? :

- Rain ☐ Wind ☐Temperature ☐ Humidity, ☐ sunshine, clouds, ☐ Other ☐

5. How are these changes experienced :

Early dry season ☐ Extreme high temperature in dry season ☐ Short dry seasons ☐

Long dry sequences in the rainy season ☐ Increase rainfall in the rainy season ☐

Decrease rain in the rainy season ☐ Longer rainy seasons ☐

b) Disruption of season i.e. rain in dry season and sun in the rainy season

Rainfall in the dry season ☐ High temperature in the rainy season ☐

6. Which of the following climatic elements will have direct impacts on the following road construction activities.

Answer with Rainfall (R) or Temperature (T) or Both (B)

a) SOIL WORK

Bush clearing and opening ☐ soil excavation cut and throw ☐

Compaction and surfacing ☐ Drainage excavation ☐

Road dressing with laterite ☐ Base course ☐

b) BITUMINIZATION

1st Priming with liquid asphalt ☐ sand flushing ☐

2rdxx Priming with liquid asphalt ☐

Compaction with asphalt ☐

7. In term of productivity

a) Does it affect the productivity of the work Yes ☐ No ☐

b) if yes, how ☐

Stops work ☐ alters work schedules ☐ destroy equipments ☐ quality ☐

Others ☐ none ☐

c) In terms of cost how does it affect the company through time ?

____

____

8. Is the company doing any thing in terms of road adaptation to climate change.

Yes ☐ No ☐

If yes what has been done

____

____

____

Does if affects the quality of work done by your company yes ☐ no ☐

If yes how, in terms of

Durability ☐ Time of project execution ☐

Has any mitigation measure been taken so far by the company for this problem

Yes ☐ No ☐

a) If yes what has been done

____

____

____

b) If no, what do you propose

____

____

____

10 Does the above climatic elements affect the heath of workers. Yes ☐ No ☐

If yes , how is it manifested ? By Malaria ☐ Typhoid ☐ Other ☐