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The Effects of climate change and land use patterns on Water and agricultural Resources in the Sahel of Cameroon Population Vulnerability and Adaptations

A THESIS
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Table of contents

List of Figures

List of Tables

Abstract

Climate change (CC) and land use patterns have reduced agricultural output, river discharge and water quality in the study area. While increase in temperatures (temp) in the Sahel is likely to reduce rainfall and increase droughts, current land use patterns of increase deforestation and irrigation to create more agricultural land are triggering food and water resource crisis. With future warming of the Sahel ranging from 0.2 degrees Celsius to 0.50 degrees Celsius per decade, the outcome of future agricultural and water resources output seems very negative in the study area.

This study therefore finds out the extent to which CC and land use patterns are affecting agricultural output; river discharge and river water quality as well as investigates the most vulnerable sex and wealth groups. The study will also seek to uncover whether the National Environmental Management Plan is sufficient and suitable in managing the crisis as well as look at the current adaptation lapses and investigate other possible means of adaptation.

Both primary and secondary data have been used as a basis for the analysis. To determine the declining agricultural output; data on cereal output from 1975 to 2005 was obtained from the cereal office in Garoua. An interview with an official in the ministry of agriculture was also helpful to determine the causes for the state of the cereal output. Secondary data on river discharge was also obtained from CEEPA to show the current trends in river discharge. River water quality was also determined through the collection of water samples and testing the latter in the laboratory for pathogens. The extent of population vulnerability, possible adaptations, the efficiency and sufficiency of the National Environmental Management Plan population perceptions of water quality and discharge was determined from responses obtained from interviews with the general public and officials in the ministries of Environment and forestry, Agriculture and Mines water and Power.

Results from this study reveal that CC, irrigation and population growth are worsening the decline in agricultural output with remarkable food shortages between 1975 to 2005. It has also worsened declining discharge in rivers and declining river water quality indicated by the presence of pathogens in river water due to increased stress on river water by population. Also, the study reveals that the most affected segments of the population are females and the poor while adaptation measures currently in place are inadequate.

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Chapter 1
Introduction

1.1 Introduction

Climate remains dynamic and changes continuously with long term cold and warm episodes. Human activities in terms of land use patterns have been linked to extreme changes in climate. Such climate variability has had lots of effects on water and agriculture. (Molua, Lambi, (2006:06).

The dry spells experienced in the late 20th century have been attributed to human factors such as increase atmospheric aerosols and increase Green House Gases (GHGs). Projections up to the 21st century illustrate that the Sahel will be drier in the future due to GHGs. If these suggestions of long terms projections of temperature (temp) rise and rainfall (RF) reductions obtains, then the Sahel will experience more droughts in the 21st century than in the 20th century (NOAA and GFDL, 2007).According to NOAA and GFDL, (2007) climate change (CC) will cause a 25 percent reduction in RF in the Sahel by 2100.

As seen above, CC can be seen as a potential big threat to the survival of human kind it is expected to increase temp and alter RF patterns. Projections of CC are however subject to uncertainties as a result of several interacting factors including, limitations of knowledge on CC and the ongoing and ever changing debates. It has been noted that future GHG emissions cannot be known with exact precision but an understanding of socio-economic and atmospheric processes can be used to produce a range of plausible values. One study of Southeast Africa projects annual RF changes of between – 35 and + 5 percent (IPCC1a). The IPCC, (2001a, b) and UNEP, (2005) also suggest temp changes for Africa of between 0.2 degrees Celsius to 0.5 degree Celsius per decade. It is also mentioned that the interior regions of the region stands at higher risks for adverse changes in RF and temp rises (IPCC, 2001b).

Shrinking agricultural productivity and river discharge are caused by changes in RF and temp that are also caused by changes in land use patterns over the long run (Olsson, 2008). As such, there has been a year to year variability in climate (IPCC, 2001b:89). Climate can

hence be seen as a key driver of food security (Gregory *et al*, 2005 and Verdin *et al*, 2005). Farmers in many parts of the world have access to physical, agricultural, economic and social resources to moderate or enhance their adaptation to the impacts of climate variability on hydrology and food production. However, in Africa the adaptation capacity to the impacts of climate variability is very low making agricultural systems particularly vulnerable (Haile, 2005). Cooper, (2004) and Allan, (1976) argue that the high vulnerability of African agriculture to CC is due to the fact that crop cultivation in Africa largely depends on RF, 89 percent of cereals cultivated in Sub-Saharan Africa (SSA) are rain fed.

1.2 Problem Statement

Increase temp and decrease in RF are likely to bring about persistent droughts which will herald further food shortages and declining water resources in the Sahel. During the next 100 years temp rise of 2 degrees to 6 degrees is projected with a parallel decline in RF. Historical climate data for Africa showed warming of approximately 0.7 degrees over Africa in the 20th century with noticeable decreases in RF over large parts of the Sahel.Future warming of the Sahelian Africa shows a temp range of from 0.2 degrees Celsius per decade to more than 0.50 degrees Celsius per decade (UNEP, 2005).

Climate remains a key uncertainty for agricultural production in the Sahel of Cameroon. In 1997 low RF brought about lots of starvation, malnutrition and poverty which attracted a lot of food aid in the region from the World Food Program (WFP). In 1998, the WFP gave another 9500 tons of food to subvert shortages in the Northern part of Cameroon. This was again repeated in 2005 following drops in agricultural output (Molua and Lambi, 2006:07).
The observed decline in RF in the study area is said to increase desertification in Northern Cameroon which enhances the effects on agriculture and water resources (Molua and Lambi, 2006:07). However, the recorded food and water resource problem in the Sahel are not only due to temp and RF variability but also due to dynamics in land use patterns over the long term. In the study area, increasing population growth, deforestation and the pressure imposed by irrigation systems are also accounting for RF variability as well as shrinking agricultural and water resource base (Olsson, 2008).

The Northern region of Cameroon has a Sahelian climate with annual RF ranging between 300mm to 500mm and concentrated to around three to four months of July to October with average annual temp exceeding 30 degree Celsius, (Nchangvi, 2004:4). As such, long term CC has invariably effected on an already highly vulnerable population. The main repercussions are declining water quantity and quality as well as declining agricultural output. An increased concentration of population has led to declining water quality and disease proliferation Mani *et al,* 2008 and Ntayike, 2004:4).

According to Adama, (2006) CC has most severe impacts on the northern parts of Cameroon. In this study it has also been shown that with a population of more than three million people, CC is a real and a severe threat as it has led to the drying of river beds, digging of the latter to get water, women and children (essentially the poor) covering longer distances to fetch water, animals and humans fighting for the same source of water (ibid). The Rivers Chari and Logone and the Lake Chad which are major hydrological networks in the area are disappearing and their flora and fauna are no exception (ibid). In 1964 when the lake Chad Basin Commission was found, the lake covered an area of about 25000km square. In 1993 it had been reduced to 5000km square and currently the lake only covers 3000km square (UNEP and DEWA, 2001). This goes to herald the notion that the dynamism of the Sahel ecosystem response to both climatic variations and human land use patterns that affect the stock of biospheric resources (Olsson, 2008).

This study focuses on the agricultural and water resource stress which remains the “key” to the survival of nature, To further support the water related stress, Ajaga (2004: 109) affirms that,” No one can ignore the fact that water is the source of life. Without it there can be no plants, no animals nor humans. The pattern of human settlements, the way of life of a people and their world view is often greatly influenced by the quantity and quality of water at their disposal.” In the Northern Region of Cameroon where climatic variations have led to a drop in the quantity and quality of water available in rivers (Chari and Logone) and in the Lake Chad the inherent stress over the declining water resources has led to a decline in agricultural output, decline and outbreaks of water borne diseases such as cholera, dysentery or general abdominal disorders. (Ntayike, 2004:4).

Due to the above changes, the number of people that starve has increased. The UN, (2005) and Bodil, (2006) argue that, the number of under-nourished people is declining in the world in average, but the rising number of under-nourished people has in the 1990s increased by 32 million in Sub-Saharan Africa (SSA).

1.3 Rational of the Study

Therefore, this study seeks to fill in research gaps by examining the consequences of CC and land use patterns on the human population in Cameroon. A large part of the population in Cameroon depends exclusively on environmental resources such as water, soil and wood resources which provide food, income, power, stability and resilience and support to rural livelihoods (Bird and Shepherd, 2003). When the latter becomes scarce, the most vulnerable segments of the population suffer the most; women because they are often in charge of household alimentation and sanitation, the poor because in most cases they have no options than to resort to poor quality water (Ntayike, 2004:4).

1.4 Objectives of the Study

This study has three interlinked objectives:

- To analyse available secondary information and primary information related to CC and land use in Cameroon and assess the possible repercussions of CC on agro and hydrological resources (quantity and quality) in the Northern region of Cameroon.

- To examine population vulnerability to CC in the North of Cameroon focusing on how gender and wealth are influential.

- Based on the results from the first two objectives the study will also examine existing and possible adaptation measures and also examine the NEMP and appraise to which extent this plan will be sufficient to adapt to the CC impacts and make recommendations for improvements where there are weaknesses.

1.5 Research Questions

From the above research objectives, specific research questions can be asked, these include:

- Based on available information, what are the effects of CC and land use on water resource quantity, water quality and agro-ecosystems in the North of Cameroon?
- Which are the most vulnerable populations to these effects in terms of gender and wealth?
- What are the existing and possible adaptation measures and is the NEMP efficient and sufficient to adapt to these problems?

1.6 The Study Area

Three specific settlements have been selected to serve as the cases for this study. They include Kousseri situated close to Lake Chad (L.C) which is the largest most affected hydrological unit, Garoua close to the Benue river and Maroua-Yagoua situated around the Logone and Chari rivers. These areas are selected because they have the following land use systems which hamper the ecosystem in the area due to excesses i) have dense concentrations of farming populations and ii) they depend on irrigated agriculture (Adama, 2006 and CEEPA, 2006). Figure 1 that follows is a map of the study area with the study sites in circles.

The hydrological units of interest are the rivers Logone, Benue and Chari. The Chari is estimated to be about 949 km Long river; it flows from Central African Republic (CAR) through Chad into L.C following the Cameroonian border from N'djamena. This river provides close to 80 percent of the water flowing into L.C. The Logone on the other hand is a major tributary of the Chari. The Benue on the other hand is a tributary of the Niger river; it is about 1400 km long and takes its rise from the Adamawa plateau (Gwanfogbe and Melingui, 1983:23).

Figure 1: Map of Cameroon locating the study sites
Source: ://images.google.se/images?hl=sv&q=cameroon+map&um=1&ie=UTF-8&ei=6QUQStHyPIXK_gb50_WVBA&sa=X&oi=image_result_group&resnum=5&ct=title

Kousseri was selected because it is close to the LC and the rivers Logone and Chari as they flow southwards. The people of Kousseri equally use these hydrological sources for irrigation. The Maroua-Yagoua area was also selected because it is close to the rivers Logone and Chari as they flow southwards, the inhabitants of these areas equally use the water for irrigation. Garoua on its part was selected because it is at the confluence of the River Benue where it gives rise to river Kabia.

Chapter 2
Materials and Methods

This chapter is divided into two main sections, the first section deals with the collection of data and the second on the analysis of the data.

2.1 Data Collection

The data collection phase of this project heralds the various techniques by which the data used in this work were obtained. In view of this, the data collection phase has been further Balkanized into two sub-phases:

Primary Data Collection

Secondary Data Collection

2.1.1 Primary Data Collection

This phase of the thesis describes the field techniques that were used to obtain new or primary data from undertaken field study in Kousseri, Maroua-Yagoua and Garoua. The fieldwork comprised of administration of questionnaires to the general public and interviews with officials and collection of river water samples for testing to detect microbiological pathogens (Williman, 2006:87).

2.1.1.1 Administration of Questionnaires and Interviews

The administration of questionnaires represents the first phase of collection of primary data. The first sets of questionnaires (see Appendix 1) for this study are those administered to the general public, the main respondents here where local fishermen, hunters, rice, groundnut and millet farmers and teachers. One hundred copies were administered as follows: 30 were administered in Garoua, 40 in Maroua–Yagoua and 30 in Kousseri. In the Maroua-Yagoua region more questionnaires (40) were administered because of the relatively larger size of the area extending from Maroua to Yagoua. The selection of these settlements to be part of the sampling frame was based on the following (see also chapter 0ne 1.6: study area).

The systematic random sampling method was used to select those to whom the questionnaires were administered. In this case, a house was selected after every 5 houses until the required number of respondents was obtained. The respondents were interviewed in

their houses to establish accuracy and determine the exact origin of the data (Williman, 2006:75) and (Bryman, 2004). The main difficulty with the administration of questionnaires was the fact that most of the respondents could not communicate in French or English. To overcome this difficulty a translator who speaks French, Shuwa Arabic, Buduma and Fulfulde was hired to translate the questions and the responses. I noted the responses in when I got the translation directly on the questionnaires.

In addition to the distribution of questionnaires to the general public, a second category of questions (see Appendix 2) were directed to officials in the ministry of Agriculture and Rural Development, Cereal office of Garoua, Ministry of Environment and Forest (MINEF) and Ministry of Mines Water and Power. In total four officials were interviewed, one from each ministry and one from the Cereal office of Garoua. The questions were designed to be semi-structured since the respondents were allowed to express themselves beyond the limits of the questions (Williman, 2006:92).

The main reason for administering these questions to these respondents was to enable a comparison between the perceptions of officials in charge of agriculture, environment, water and CC adaptation with those of the local farmers. In view of the fact that there is very little secondary information on the Sahel of Cameroon and CC, these perceptions would provide an inside into the main effects from the sufferers' point of view (Williman, 2006:87).

The questionnaires to the general public and questions to officials enabled the collection of information related to agricultural output, river discharge, river water quality and population vulnerability and how this is related to gender and poverty, possible adaptation measures, suitability and efficiency of NEMP.

2.1.1.2 River Water Sample Collection

To evaluate the status of river water, water samples were collected from the rivers Benue, Logone, Chari and the L.C. In total two samples were collected from each hydrological unit giving a total of 8 samples collected. The sampling sites were those seen as areas regularly visited and used by the people for bathing, laundry, fetching of drinking, cooking water or other domestic uses in general. (Williman, 2006:43). The samples from the river were

collected to determine the extent of water pollution from human activities (Berry and Horton, 1994).

The water samples were collected in sterile plastic containers (250 ml). Each sterile container was unscrewed at the river bank. A wedge to increase the weight of the container was tied at the mouth of the container along with a rope (about 25 m long). The rope and the container were sent down the river from the banks. At water level, the wedge descended the container down the water so that water could be collected. After the container was filled, the rope was pulled out of the river. The container was aseptically screwed, labeled and placed in a sterilized ice packed box.

The use of ice as a transporting medium was based on the premise that the ice reduces the rate of enzyme action within the organisms and keeps them alive during transportation (Cheesbrough, 1984). The samples were then taken to the laboratory of the University of Ngoundere for experimental microbiological analysis (Williman, 2006:43).

The samples were collected on the 24the of January 2009. The choice of the sampling period was based on the premise that during the dry season there are larger shortages of water and the rush for water might lead the masses into consuming contaminated and unsterilized water thus making the effects of CC more visible.

2.1.2 Secondary Data Collection

A literature search of existing data expounding on CC in the Sahel, effects of the latter on agricultural output, water quality and quantity in general and population vulnerability and adaptation in particular. These were obtained from Lund University Geolibrary, the library of the University of Buea, the libraries of the Ministries of Agriculture, Environment and Forestry and Mines water and power. Some of the secondary literature was obtained from some websites on the internet.

The reviewed works either dwelled on the situation in the Sahel or other parts of the world but were still very vital in understanding the specific problems of the Sahel of Cameroon, Bryman, (2004). This literature study has helped in laying a foundation of understanding of the key concepts associated to the problem and thus increase the understanding of the

general objectives of this study. As such, this has enhanced articulation of the problem under study.

Other secondary sources of information exploited included maps, tables and graphs of the development of the agricultural output in the study area, RF deviation graphs, and river discharge data for parallel area for selected rivers in the area obtained from CEEPA, 2006. Other river flow data such as the declining inflows into the LC after the 1970s was also collected. These data has been used to determine the impact of CC on river discharge. Data on declining agricultural output was obtained from the Cereal office and the North Regional Delegation for agriculture and Rural Development.

2.2 Data Analysis

2.2.1 Analysis of Questionnaires

This phase of data analysis has made use of the statistical package for social sciences (SPSS) and Mapsys. These have assisted in the analysis of the questionnaires. This has been done by coding the questionnaires to come out with different perceptions of the population and officials with respect to the various objectives of the study. After the coding, the data was entered into the software based on the created categories. The software was then run to come out with the different trends further discussed in chapter 4.

From this analysis it has been possible to identify the perceptions of the general public in the area with respect to the effects of CC on agricultural output, water resources, population vulnerability, adaptation and the efficiency and suitability of NEMP.

2.2.2 Analysis of Secondary Data

Firstly, the deficits of agricultural production for each year from 1975 to 2005 was calculated. This was done by subtracting the raw data on anticipated production from the raw data on actual production for each year. The mean values of agricultural output and anticipated production were calculated for each five year period to be able to establish a relationship between actual production and required production that will fulfill the needs of the population. These calculations were done by grouping the raw data on actual and anticipated agricultural output in groups of 5 years spanning the period 1975 to 2005. After the grouping into periods of 5 years, the means for each 5 year period was calculated by

adding up the 5 different outputs for the different periods and dividing by 5.This was now represented on a chart covering the means of actual and required agricultural production from 1975 to 2005.

The variations in river flow were analyzed as the data from CEEPA, 2006 was plotted on graphs to show rates of flow for the dry and rainy seasons. To effectively evaluate the NEMP, the document was specifically read and the parts that apply to the study are specifically considered, the weaknesses in addressing the situation were also recorded. On the issue of adaptations literature was surveyed to outline the existing and possible adaptation measures. Mapsys modeling software has been used to conceptualise the problem into a conceptual model presented in chapter 3.

2.2.3 Water Quality Analysis

The 8 river water samples that were collected were subjected to the following analysis:

Microbiological Analysis of Water Samples

Purification and Maintenance of Isolates

Identification of Isolates

2.2.3.1 Microbiological Analysis of Water Samples.

The water samples were cultured on alkaline peptone water with a pH of 8.6. Alkaline peptone water with pH 8.6 renders the medium selective for the enrichment of Vibrio species that cause cholera. These preparations were incubated in test tubes at a temperature of 37 degrees Celsius for 24 hours as described by Cheesbrough, (1984).

On the second day the incubated samples were sub-cultured on Thiosulphate citrate bile salt sucrose agar (TCBS). The TCBS was prepared by dissolving 8.8 grams of TCBS powder in 100 ml water. This mixture was boiled at 100 degrees Celsius and allowed to cold down to 37 degree Celsius. The mixture was then poured on 4 Petri dishes.

The alkaline peptone water broth (0.1 ml) was then sub- cultured on the sterile TCBS agar plates (Petri dishes). A sterilized wire loop was used to streak the alkaline peptone water on the TCBS (streaking method). The preparation was done in duplicate and incubated at 37 degree Celsius for 14 hours. The original colour of the media in the Petri dishes was blue.

After 14 hours incubation the plates were observed to establish the presence or absence of large colonies of sucrose fermenting organisms (SFO). Growth patterns were recorded as + (scanty), ++ (moderate) and +++ profuse growth. Samples were analysed in duplicates. This means that since 8 samples were collected 4 Petri dishes were used and each Petri dish was used to culture 2 samples. Note that sub-culturing on TCBS is based on the fact that TCBS is a medium that is also selective for Vibrio cultivation. Other organisms may not survive in this medium.

2.2.3.2 Purification and Maintenance of Isolates

After 14 hours incubation suspected colonies were purified by sub- culturing 3 times on TCBS agar medium and they were maintained on Nutrient agar at 40C awaiting further analyses.

2.2.3.3 Identification of Isolates

All the colonies were subjected to motility test and gram staining or gram reaction. Motility was determined by observing the organisms using a microscope to determine whether observed organisms were living and motile. Gram staining was used to classify the organisms as gram positive or gram negative (Cheesbrough, 1984).

The organisms were smeared on glass slides by passing the slides over the Burnsen burner flame. Crystal violet was then poured on each slide and washed over slow running water of a tap after 60 seconds; this was followed by the application of iodine which was also washed off using tap water after 60 seconds. Then, alcohol (ethanol) which is a decolorant was applied. The alcohol was left for about 60 seconds and again washed under slow running tap water, safranin was then applied. The slides were then allowed to dry at room temperature after which they were observed under a microscope. Organisms that were gram positive appear purple after gram staining while those that were gram negative appeared pink.

Generally, presumptive or infected colonies were expected to be highly motile, oxidase positive and presenting a gram negative curved rod shape organism. Oxidase strips were used to determine whether the samples were oxidase positive or not. These strips were

placed in contact with each sample. Those that were oxidase positive experience a growth of greenish bacterial colonies, had high motility and had Vibrio.

2.3 Limitations of the Methodology

The above methodology has the following weaknesses or limitations:

1. Firstly, the use of samples during the interviews has subjected the study to internal or statistical errors.

2. Secondly, this study is entirely in English and all the questions are in English. However, most of the respondents in the area either speak Shuwa Arabic, Buduma, Fulfulde and a minority speaking French. As a result, it is possible that the researcher might have experienced a miscomprehension of some of the translated facts (see administration of questionnaires above) which might lead to a loss of facts.

3. Furthermore, the sample size of 100 questionnaires administered to the general public and four to the three ministerial departments and the cereal office concerned is still small; only 8 water samples were collected as well. However, time and cost issues made it difficult for larger samples to be collected.

4. Finally, CC remains a complex issue and very few studies are available covering the area, this made it difficult to get concrete and to locate specific secondary information on the state of the art situation of CC. Consequently, this study has to a large extent relied on the population's perceptions obtained from the interviews and the results of tested water samples.

Chapter 3
Climate Change impacts and Conceptual Framework

This chapter consists of a review of general literature on CC that will assist in placing the objectives of this study into perspective. This chapter gives brief review of the variations in temp and RF in SSA in general. This is thereafter followed by a conceptual model or a causal loop diagram (CLD) showing the interactions between the different actors.

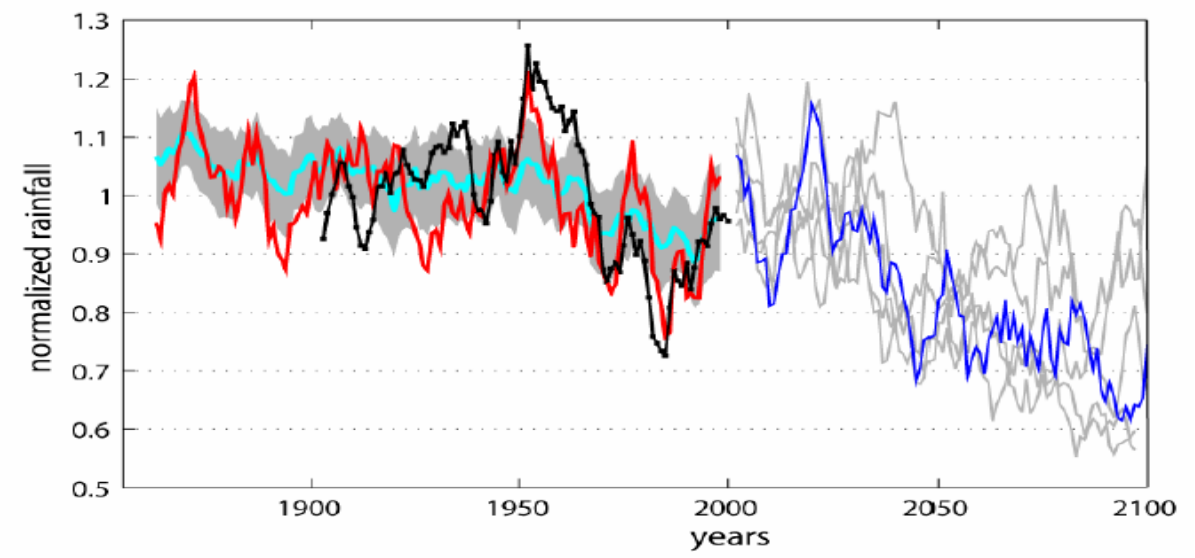
3.1 Climate Change in the Sahel

The IPCC, (2007:17) argues that most of the recorded increases in global average temp in the 20th century have been due to anthropogenic GHGs. In the main, African countries with low Gross domestic product (GDP) tend to show lesser ability to adapt to these changes due probably to low GDP (ibid: 15). There is thus scientific consensus that the earths global climate is changing as global mean temp increased by 0.6 degrees Celsius last century with the hottest years ever in record occurring after 1990 (Serigne *et al*, 2006). According to the IPCC, 2001, a decrease in RF in the Sahel of 29-49 percent was observed during the 1968-1997 period compared to the 1931-1960 baseline.

Figure 2 is an illustration of the variations of RF in the Sahel between the 20th century and projections for the 21st century. The Sahelian droughts of the late 20th century were caused by both internal and externally forced variability. By averaging the eight individual experiments the ensemble mean climate response is recorded and it is given by the blue line on the figure. The drying trends experienced in the late 20th century are attributed to human induced factors such as GHG emissions and aerosols (GFDL and NOAA, 2007).

In the 21st century scenario projections of the CM2 models speak of a drier Sahel in the future due to more GHGs.If this obtains then the Sahel will experience declining RF and more severe droughts in the 21st century than in the 20th century. This has been simulated by a further decline in the blue line within the 21st century (GFDL and NOAA, 2007).

To further illustrate the declining RF within the 20th century, Serigne *et al* (2006:09), argue that there has been very little deviations of the RF below the mean RF of zero between 1922 and 1968. Rather, positive RF deviations were recorded. This of course can be attributed to the limited CC and land use change at the time. However, after 1968 there has been frequent and high negative deviations below the mean of zero and very few years where RF has been above the mean.



[Above] 5-year running means (July–Aug.–Sept.) of Sahel rainfall, normalized so its average value over 1901–2000 is equal to 1.0. Black curve = observations. Thick light blue line = historical CM2 ensemble mean (n=8). Red line = CM2 simulation that most resembles the observed 1950-2000. The gray area represents ±1 standard deviation within the ensemble. The six curves for 2000-2100 are projections for thee future emissions scenarios, one each from CM2.0 and another from CM2.1. The dark blue line shows results from the CM2.0 SRES A1B experiment. See Held et al. (2006) for details.

Figure 2: Normalised 20th century Rainfall in the Sahel and Projections for the 21st Century
Source: GFDL and NOAA (2007)

Due to the above recorded variability in Sahelian RF, the Sahel has become a main receptor of global 'attention' because of its persistent droughts, famine and political crisis. It has been further acknowledged that both climate variability and land use patterns are affecting the

Sahel's productivity. A further close correlation between changes in RF, land use and primary productivity has been established (Olsson, 2008).

The people of the Sahel experienced devastating droughts and famine in the 1960s and 1990s. The scientific argument about the causes of these droughts remains a continuum in the debate and the assertion on reclining RF in the Sahel has been greatly questioned and the discussions attained a zenith with the droughts of the 1960s and 1970s.The initial discussion attributed the occurrence of the droughts to human exploitation but the more recent explanation creates the balance between the human and the natural causes (Olsson, 2008).

Olsson, (2008) uses the" cherney hypothesis" to further explain the reasons for the decline in RF in the Sahel. The hypothesis holds that as the albedo of the landscape increases with increase cultivation and over grazing there is a generalised cooling of the surface and a consequent reduction in evapotranspiration and surface air convergence which further reduces RF and through a reduction in cloudiness.

To further explain the declines in RF recorded in the Sahel, Olsson, (2008) uses the work of the Goddard institute to argue that as albedo changes from 14 percent to 35 percent over continental deserts, there will be a reduction in cloud formation and RF.

However, recent time series data shows that the Sahel has experienced increase greening correlated to increasing RF during the periods 1982-1993 and 1994-2003.Therefore, a more balanced attribution of the current decline in agricultural output and river discharge in the Sahel of Cameroon would not only concentrate on RF and temp variability but would also look at the systems of land use which are equally hampering on RF negatively. This would be more balanced since current research shows that RF is increasing (Olsson, 2008). That not withstanding, the future trends in Sahelian RF as discussed by GFDL and NOAA, (2007) show a decline in RF in the 21st century. From these reviews, the debate remains tense and it therefore becomes difficult to subscribe to only CC as the main factor affecting agriculture and river discharge in the area. This is the reason why this study is also attributing the changes to land use patterns.

3.2 Conceptual Model

This study has using Mapsys modeling software constructed a Causal loop diagram. Figure 3 summarises the key conceptual issues on which this study is based. The general dynamics of the system are as follows.

Climate change has as argued previously, increased temp (caused by increase GHG emissions, increase use of aerosols, deforestation and more intensive cultivation) and decrease RF in the area. This has a negative effect on the availability of water in rivers which also leads to a decline in irrigation capacity. This will lead to a decline in agricultural output. Declining RF will mean more droughts and this will directly reduce agricultural output since rain fed agriculture will decline. A decline in agricultural output will lead to increased poverty and malnutrition which are indicators of low population adaptability.

The high poverty and malnutrition levels will illustrate low adaptability due to a reduction in the population's access to farm inputs and this will even reinforce the decline in agricultural output. Increased incidence of poverty among the people will further reduce adaptability due to reduced access to pipe borne water. This will therefore increase environmental degradation indirectly by an increase population concentration on river banks, as more people will gather on the same places to find water. This will lead to a decline in river water quality. Decreased river water quality, will as argued by Mani *et al* (2008:03), lead to increase diarrheal diseases. This in turn will reduce population if the disaster is not arrested by adequate adaptation.

However, currently the population is growing due to increasing birth rates which accelerates deforestation for the purpose of farm land creation. This is so because the pressure on land increases as most of the people cut off the forest to create farm lands. This inturn leads to increased environmental degradation. As Kabat *et al* (2004:439) argue, trees have the capacity of holding water in the soil and therefore their absence leads to a degradation of soil. This inturn reinforces the reduction in agricultural output.

Also, it is possible that increase deforestation would increase the level of atmospheric Carbondioxide thus increasing temp; this has not however been included in the CLD because

this is a slow process and it is more feasible at the global scale. Also, the study area is not heavily industrialized yet deforestation has been very rampant, causing mainly environmental degradation. The two main factors influencing the vulnerability of the population are population growth and CC that are leading to the same result, decreasing availability of water resources, decreasing agricultural output and environmental degradation.

However, following the complex nature of the debate, some schools of thought hold that RF in the Sahel is rather increasing at the moment. This has been explained by the increase rate of greening observed in the area (Olsson, 2008). As such, it becomes hard to conclude that the decline in river water levels, agricultural production and irrigation capacity are entirely due to RF. Therefore, the observed effects on river water levels and agricultural production can more adequately be explained in the context of the interaction between CC and land use change.

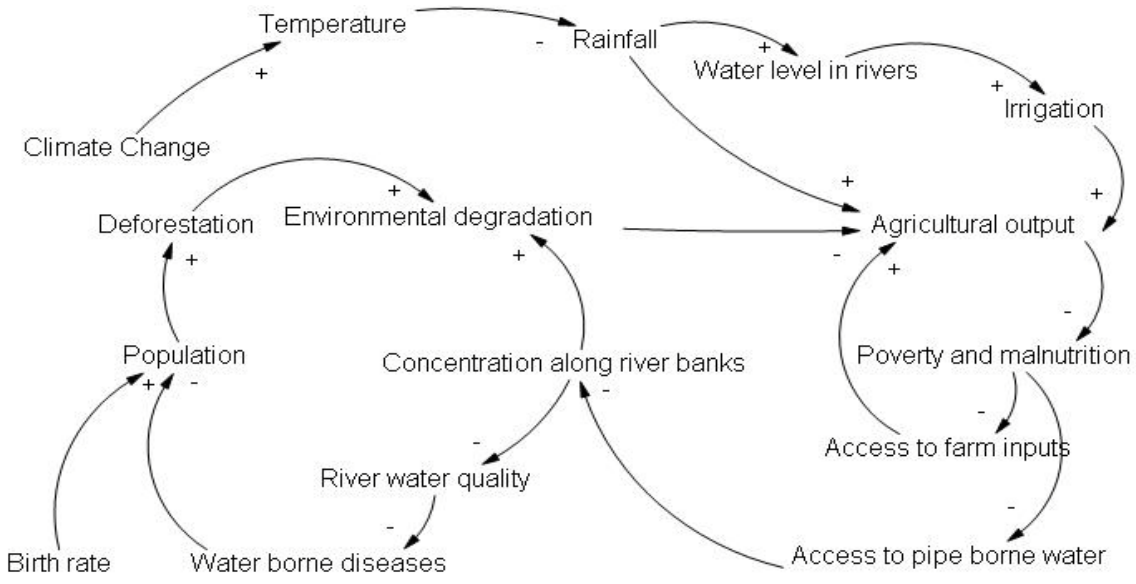


Figure 3: CLD model showing the interactions between the primary drivers

Chapter 4
Results and Discussions

This section dissects the collected empirical material to shed light on the main objectives and shall thus try to substantiate the objectives. It shall therefore look at the effects of CC on agriculture and water resource quantity based on collected secondary and primary data. This shall be followed by a look at the analysis of the quality of the water available in most of the streams, population vulnerability, adaptation capacity and the possible efficiency of NEMP based on primary data.

4.1 Climate Change, Land Use and Agricultural Output, River discharge and River water Quality in the Sahel of Cameroon

In general terms, Cameroon has been described as a 'bread basket' in the African continent. This is because the country is generally very productive when it comes to agriculture. In this context, almost every tropical food and cash crop is grown in the country. It has been a main supplier of food products in many African countries (Bunyui, 2006:62).

However, the agricultural situation of the country has lots of spatial disparities. Much of the output comes from the South which has regular RF amounting to over 1500mm annually and 26 degrees Celsius (Bunyui, 2006:54 and Tsala *et al*, 1985:08). As such, in the midst of plenty in the Southern region there is a spectre of hunger in the Northern region which has experienced declining agricultural output caused by CC and land use changes (Bunyui, 2006:62).

The resultant decline in agricultural output is closely linked to declining RF, rising temp and changes in land use systems which have all contributed in varying dimensions. Declining irrigation capacity for example has led to increase searches for water and stress along river banks with river water now being polluted. The sections that follow below now attempt at exemplifying the complex interactions between climate and land use change.

4.1.1 Climate Change, Land Use and Agricultural Output

According to the IPCC (2007:26) average temp of 1.5 to 2 degrees Celsius will likely cause about 20-30 percent of plant species to be extinct. It is argued further that due to climate

variability and the effects of land use systems of irrigation, deforestation and population growth and increased agricultural intensification, agricultural output and availability of food resources is being greatly reduced in many SSA countries. This is caused by changes in the length of the growing season and a reduction in the area suitable for cultivation in semi-arid areas (IPCC (2007:13). Other effects of this will be reduced food security and increased malnutrition in Africa in general and SSA in particular. Furthermore, in some parts of the continent, rain fed agriculture might be reduced by up to 50 percent by 2020 (IPCC, 2007:13). Furthermore, IPCC, (2007:13) argues that local food supplies are projected to be negatively affected by increasing temp. This is because the resilience of the system will be exceeded by a combination of CC and land use change factors such as over exploitation of resources (IPCC, 2007:26).

The issue of declining food resources due to rising temp and declining RF is so crucial for the African continent because, as IPCC, (2007:48) puts it; agricultural production is dependent on natural capital and these are linked to local livelihoods in many but not all parts of African states. CEEPA, (2006:01) reaffirms this when it notes that Cameroon is an agrarian economy with 73 percent of its active population involved in the agricultural sector.

The Far North of Cameroon is most vulnerable since it has a Sahelian climate with low and erratic RF, high population density of 200 persons/km square (Bunyui, 2006:208-209) which further increases population stress on limited resources. The yearly rains last about 4 months spanning from July to October. The RF variability in the area ranges from 73 percent to 95 percent in this zone and this shows how unpredictable and precarious the climate of the region is and the problems it creates for agriculture (CEEPA, 2006:01). It is now clear that in the low latitudes and especially in dry tropical regions such as the Sahel of Cameroon, slight temp increases of 1 to 2 degrees Celsius would increases the risk of hunger and cereals are at great risk of the projected decrease (IPCC, 2007:26).

According to IFAD, (2001) the Sahel of Cameroon in general and Africa in particular is a hunger threatened region. Projections show that by 2020, food shortages would have reduced in most developing countries but the Sahel will still be facing problems with food shortages due to inappropriate land uses such as over cultivation, irrigation and rapid population

growth (IFAD, 2001). Figure 4 below illustrates that there are three different future scenarios for food security in the Far North, optimistic, baseline and pessimistic. Even if, cereal outputs will rise in SSA it's however quite possible that due to an increased population the growth in production will be worthless (IFAD, 2001) and the amount of malnourished children will keep on a pessimistic turn towards 2020.

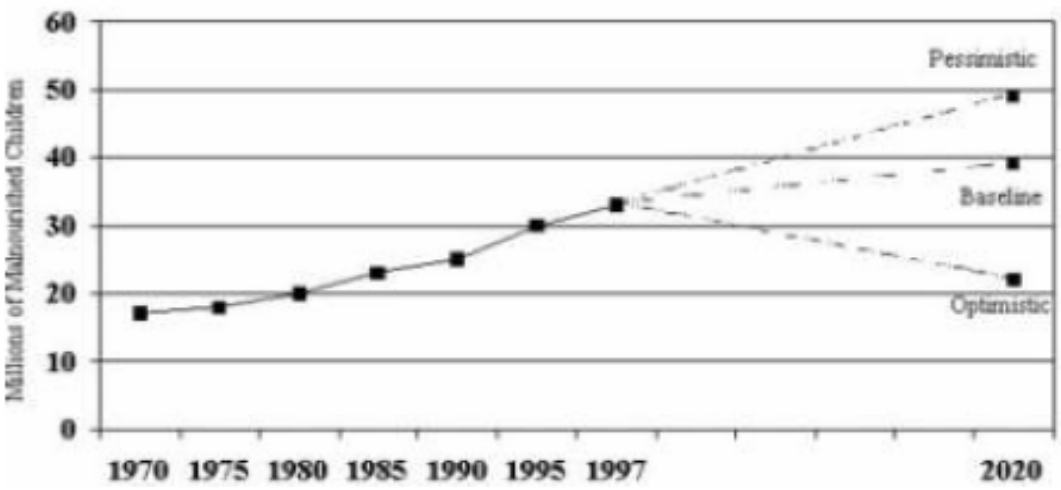


Figure 4: Projections of food security situation in the Sahel to 2020
Source: IFAD, 2001

Table 1 below is a demonstration of the acute food shortage in the study area which has been worsened by CC and land use change. In the Extreme Northern region, years of agricultural shortages were 1977/78, 1979/80, 1981/82, 1983/84, 1984/85, 1987/88, 1988/891990/91, and all the years from 1993 to 2005. In the Northern region, agricultural shortages have been recorded for all the years from 1975 to 2005 with the exception of the 1992/93 agricultural year.

While acknowledging that all the deficits above are due to low RF and rising temps, officials at the cereal office hold that the 1992/93 blip was due to agricultural intensification through extension advice and provision of free fertilizers and other implements to farmers. The projects put in place to deal with food deficits however failed due to corruption of some officials and misappropriation of the funds. According to officials of the Cereal office in

Garoua, the funds did not meet the target populations as relatives of officials who did not merit assistance got most of the aid, the result has been persistent cereal shortages. In figure 5 and 6, the averages for each group of 5 years of actual and projected agricultural output has been calculated to simplify the data and to enhance analysis.

It is also necessary to specify that the quantity needed was obtained based on the population growth in the country of 2.7 per annum (Bunyui, 2006:208). Therefore, the expected production was based on the population growth in the area. This was done by the Cereal Office to be able to anticipate production that will meet the needs of the entire growing population.

Table 1: Trends of Agricultural Output and Quantity Needed from 1975 to 2005

Extreme North Region				**North Region**		
Year	**Total Production (Tons)**	**Quantity Needed (Tons)**	**Deficit or Surplus (Tons)**	**Total Production (Tons)**	**Quantity Needed (Tons)**	**Deficit or Surplus (Tons)**
75/76	253 683	229 161	+ 24 522	71 000	78 725	- 7 725
76/77	267 458	235 190	+ 32 268	77 083	82 765	- 5 682
77/78	230 092	241 365	- 11 273	66 044	87 020	- 20 976
78/79	289 485	247 722	+ 41 763	71 000	91 503	- 20 503
79/80	251 292	254 243	- 2951	77 457	96 201	- 18 744
80/81	262 841	260 928	+ 1913	68 973	101 144	- 32 171
81/82	207 341	267 793	- 60 452	51 331	106 352	- 55 021
82/83	381 153	274 840	+ 106 313	55 144	102 298	- 57 154
83/84	223 298	282 066	- 58 768	49 499	117 555	- 68 056
84/85	127 041	289 474	- 162 433	68 186	123 598	- 55 412
85/86	364 532	297 112	+ 67 420	89 831	129 954	- 40 123
86/87	450 395	304 799	+ 145 596	101 799	136 656	- 34 857
87/88	424 406	312 814	- 111 592	85 201	143 653	- 58 452
88/89	292 803	321 043	- 28 240	82 640	151 045	- 68 405
89/90	359 528	329 486	+ 30 042	99 952	158 813	- 58 861
90/91	245 992	338 158	- 92 166	125 862	166 977	- 41115

91/92	402 234	347 044	+ 55 190	126 755	175 550	- 48 795
92/93	432 517	356 176	+ 67 341	186 346	184 568	+ 1778
93/94	180 200	365 538	- 185 338	173 948	194 061	- 20113
94/95	180 000	367 500	- 187 500	190 432	199 631	- 9199
95/96	241 500	445 477	- 203 977	213 675	218 145	- 4470
96/97	355 000	468 000	-113 000	218 453	222 782	- 4329
97/98	384 000	491 256	- 107 256	264 293	231 256	+ 33037
98/99	300 857	491 332	- 190 475	327 781	330 294	-2513
99/00	329 372	495 345	- 165973	374 623	387 628	-13005
00/01	325 321	496 221	- 170 900	213 111	221 471	- 8360
01/02	323 022	498 010	- 174 988	309 558	312 937	- 3379
02/03	320 213	498 376	- 178163	313 847	319 528	- 5681
03/04	318 987	498 518	- 179531	345 163	349 814	- 4651
04/05	315 025	499 259	- 184234	373 582	379 653	- 6071

Source: Cereal Office and Ministry of Agriculture and Rural Development, (2009)

The main difference between the Extreme North Region and the North Region is based on the fact that the Extreme North Region is at the Northern tip of the country close to Chad with its capital being Maroua while the North Region is in the South of the Extreme North with the capital being Garoua (Tsala *et al*, 1985). Furthermore, while the Extreme Northern has the pure Sahel savanna vegetation and the Sahel type tropical climate with temp of more than 28 degrees Celsius and RF of 400 to 900 mm annually, the North region on its part has the Guinea savanna vegetation and the tropical Sudan type climate with RF of between 900 to1500 mm and temp of over 28 degrees Celsius (Tsala *et al*, 1985:08).

Figure 5 below shows the trends in mean actual production and the mean quantity needed. With the exception of the period 1975 to 1990 when production exceeds quantity needed, from 1990 to 2005 the quantity needed exceeds actual production creating food deficits in the Extreme North Region.

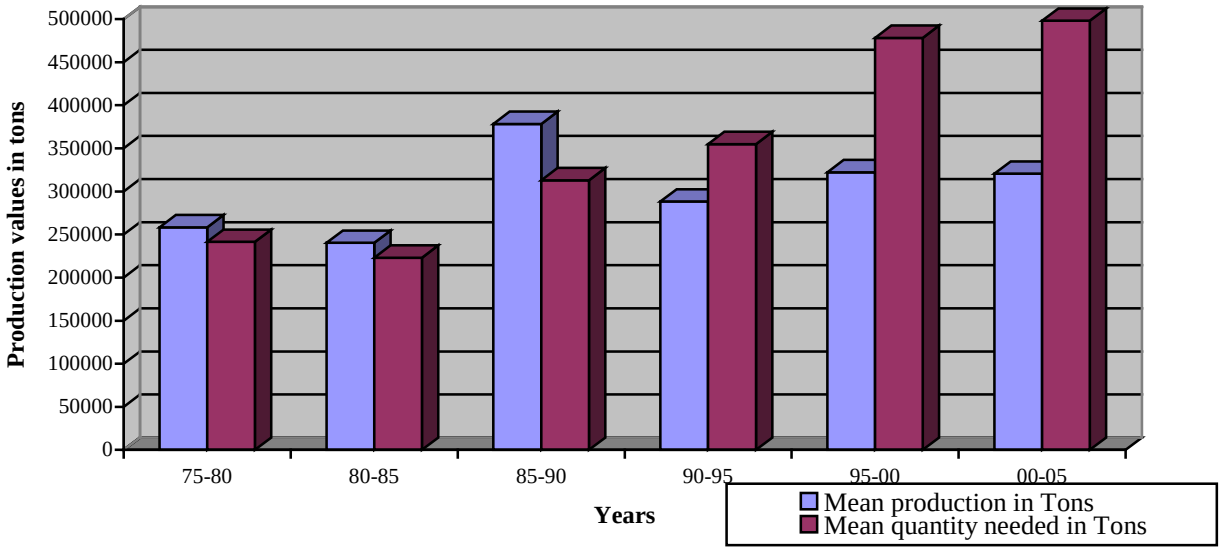


Figure 5: Mean trends of Quantity Produced and Quantity needed in the Extreme North

Figure 6 represents the mean trends of Quantity produced and Quantity needed in the North Region. As seen in the figure, the quantity produced is less than the quantity needed in all the years with the exception of the 1995-2000 agricultural year when a negligible surplus was recorded.

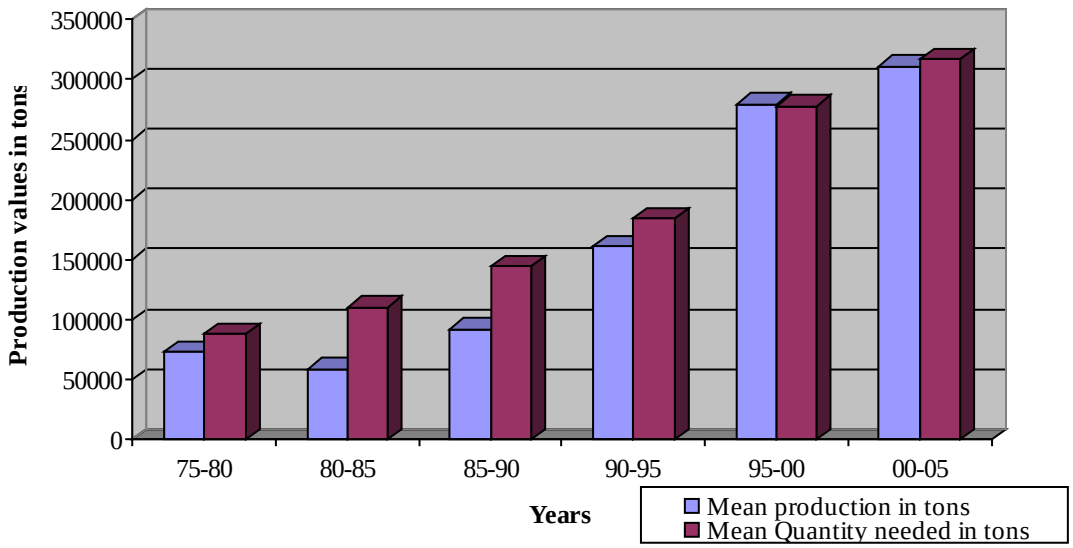


Figure 6: Mean trends of Quantity Produced and Quantity needed in the North Region

According to officials in the ministry of Agriculture and Rural Development and the Cereal office in Garoua, the blips where agricultural output exceeded quantity needed in both figures was due to short term mitigation measures such as provision of farm implements, fertilizers and extension information or technical knowledge on the intensification of reforestation in the area. These were however short lived because of the same reasons given in the case of the Extreme North above and emphasis this far was on mitigation and not adequate adaptation to the repercussions of CC.

4.1.2 Effects of Climate Change and land use on Rivers, Lake and Stream Discharge

According to IPCC (2007:13) by 2020, over 75 to 250 million people are projected to be exposed to increased water shortages due to CC and land use change. If coupled with increased demand for water; this will adversely affect livelihoods and increase water-related problems. Runoff is projected to face a decline of 10 to 30 percent over some dry regions in the tropics due to higher rates of evapotranspiration and low RF and Africa remains one of the main zones that will suffer from this decrease water resource due to CC and fluctuating Land use patterns (IPCC, 2008: 29 and Olsson, 2008).

IPCC(2007:28) and CEEPA, (2006: 01), note that the persistent change in climate recorded in the area has led to several droughts in mid latitude and semi arid low latitudes which have also had a fair share of effects on river discharge. As opposed to the well watered southern

region, the semi arid less watered northern parts of Cameroon mostly has streams whose flow is impermanent given this regions prolonged dry season (CEEPA, 2006).

According to the policy note document number 33 of CEEPA, (2006), RF variability within the Sudano-Sahelian zone from which part of this study is carried out ranges from 73 percent to 195 percent. This high variability is an indicator that low RF and rising temp will equally impact stream discharge. However, based on existing data, river discharged in the region cannot be explained entirely based on RF variability since some studies report of increase RF in the Sahel (Olsson, 2008). We can therefore argue that the observed decline in discharge is a function of interplay of population growth, increased deforestation, increased usage of river and lake water for irrigation and CC which is simply worsening the situation.

The lowest discharge of river Benue in Garoua is about 0.03L/S/km square while the peak discharge ranges between 30-50L/S/Km square (CEEPA, 2006). To be able to understand these figures, it will be necessary to compare them with the discharge recorded in the wetter south. The river Vina Lahore in the south has its lowest discharge of 1.4L/S/Km square and its peak discharge is 89L/S/Km square (CEEPA, 2006). These figures show that CC has worsened an already bad situation of the river discharge in the North of the country when compared to the south. In the North, all values for the low and peak periods are lower than the parallel values in the south.

Figure 7 that follows tries to represent these values. During the period of low flow the discharge from the Vina exceeds the Benue by 1.37L/Km Square. At the corresponding period of peak flow or discharge, the Vina still exceeds the Benue by 39L/Km Square assuming a maximum flow for the river Benue of 50L/Km Square. Note that the peak discharge for the Benue river ranges from 30 to 50L/Km Square. However, it is difficult to compared and conclude with these figures because the two rivers are in two different environments, The Benue is however suffering most due to the fact that CC has simply worsened a bad situation.

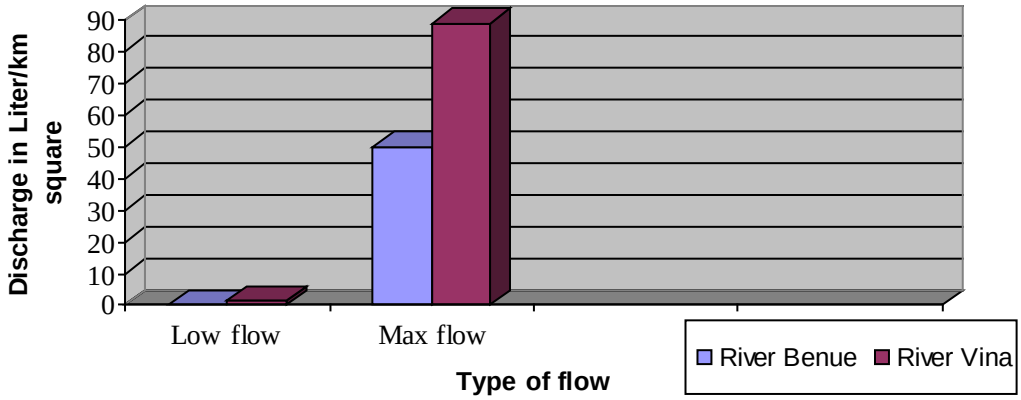


Figure 7: Comparative view of Maximum and Minimum discharges for rivers Benue and Vina

To further express the magnitude of the problem. L. C which has been a major source of economic power in the area has shrunk by 70 percent from 1964 to 2001. In 1964 when the lake Chad Basin Commission was found, the lake covered an area of about 25000km square. In 1993 it had reduced to 5000km square and currently the lake only covers 3000km square (UNEP and DEWA, 2001).

According to Science Daily (2001), the shrinking of L.C is partly due to an increase use of water from the lake by the rising population for irrigation which has caused the Lake to shrink by 20 times its original size over the past 30 years. Figure 8 that follows is an illustration of the different phases in the decline of the waters of the L.C from 1963 to 2001.

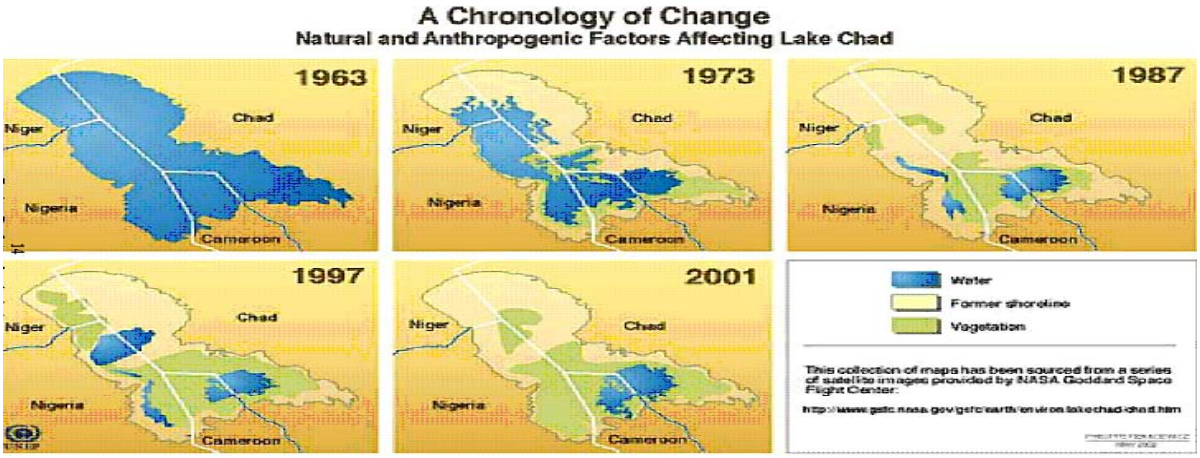


Figure 8: Phases of decline of waters in Lake Chad
Source: UNEP and DEWA, 2001

To further demonstrate the fact that population growth, irrigation and deforestation are exerting a heavy toll on the discharges of the L.C. Table 2 that follows summarises the mean inflows and outflows into the Lake in Km cube per year during the pre 1970 period as one category when inflow into the Lake was high and the 1971-1990 period when inflows dropped. All the main sources of inflow into the Lake experienced reduced discharge into after 1971 while before 1970 the mean inflow was higher. As seen further in table 2, before 1970, outflows from the Lake such as evapotranspiration, infiltration and total outflow were higher than their corresponding outflows after 1971 (Oyebande, 2003).

The overall impression here is that rising temps and declining RF and increased demand for irrigation and increased population are causing reduced inflows into the Lake and reduced outflows from the Lake leading to a lower net water balance. Therefore, it is difficult to subscribe only to CC as the cause of the observed declines in discharge.

Table 2: Drainage Areas, Inflows into Lake Chad and the Overall water Balance of the lake

	Catchment Area (km^2)	Inflows and Outflows (km^3/yr)	
		Pre-1970 mean	1971-1990 mean
Inflows			
Chari-Logone	590,000	39.8	21.8
Komadugu-Yobe	147,840	1.0	0.45
Yedseram-Ngadda-Ebeji	53,720	0.89	0.12
Other Rivers		1.2	0.2
Total River Inflows		42.89	22.57
Rainfall on open water surface		6.0	2.1
Total Input		48.89	24.68
Outflows			
Evapotranspiration		43.0	23.1
Infiltration		3.0	1.4
Total Outflow		46.0	24.5

Source: Oyebande, 1997 and UNEP and DEWA, 2003

From the table above, we observe that the average level of discharge per metres cube per second for the Benue, Mayo Kebi and Logone stand (figures in metres cube per second) at

386, 100 and 551 respectively. Due to the above very low discharge in the rivers of the region during low season droughts becomes rampant. Their corresponding flow during the periods increases the problem.

When asked to comment about river discharge in the area, most of the respondents state that the river levels have dropped considerably in their life time. To them this is seen as before the banks of the rivers flooded during the dry and rainy seasons leading to much irrigation and fishing but today one can walk on the river's bed and irrigation of farmlands has become a problem. Of the 100 respondents contacted, 64 said river levels have dropped over their life time, 30 said there has been no change in river levels while 06 said they have no idea whether it has dropped or it is fixed.

4.1.3 Climate Change, land use and Water Quality

Water is a very important resource to man's life. It is bound to have a great impact in the life of any human being and the ranges of its requirements have increased with greater demands for higher quality (Monkiedje, 1998). According to The World Health Organization (WHO, 1971) Manual on good drinking water, good water should have no odour, colour and taste. Unfortunately, due to water scarcity in the Northern Region of Cameroon there has been increased stress on available water resources which has resulted in poor handling of water and resultant contamination. Writing on the same subject, Yillia *et al*, 2008 argues that in stream activities were also responsible for reduced water quality on the Njoro River in Kenya. In stream activities are defined by these authors as the activities of people and livestock which take place besides or within streams. Mani *et a*l, (2008:01-02) note that CC will lead to an increase in the incidence of Malaria and diarrheal diseases in Africa.

The IPCC, (2007) reaffirms this when it notes that CC and systems of land use such as over utilization of river water due to increase population along river banks will enhance the burden of diarrheal diseases. This leads to the out break of water borne diseases with negative consequences on users and the entire environment ranging from poor to loss of environmental aesthetics (Berry and Horton, 1974).

The importance of clean and safe drinking water for the global community was highlighted in 1980 when the United Nations general assembly formally declared the decade 1981-1990 as the international drinking water supply and sanitation decade (United Nations, 2005).

The effects of CC on water quality are indirect, due to increasing water scarcity; population pressure on the available sources of water produces stress on the resource which results in declining water quality. As such, to be able to substantiate this sub objective properly, water samples have been collected and microbiological analysis conducted based on the steps described in the methodology. A total of 8 samples were collected (2 from each of the following rivers and lake (Benue, Logone, Chari and Lake Chad) and the results from the analysis are presented on table 3 follow.

Table 3: Microbiological characteristics of river water after Culturing on Thiosulphate Citrate Bile Salt Sucrose Agar (TCBS)

River water sample	Isolate Identification	Oxidase Reaction	Growth on TCBS	Growth Pattern	Gram Reaction	Motility	Putative Organisms
1	Benue	+	+G	+ + +	Gram – curved rod	+	Vibrio
2	Benue	-	+ Y	+	Gram - rod	-	Non Vibrio
3	Chari	-	+Y	+ +	Gram - rod	-	Non Vibrio
4	Chari	+	+ G	+ ++	Gram – curved rod	+	Vibrio
5	Lagone	-	+ Y	+	Gram - rod	_	Non Vibrio
6	Lagone	-	+Y	+	Gram - rod	-	Non Vibrio

7	L. Chad	+	+ G	+ +	Gram - rod	+	Vibrio
8	L. Chad	_	+ Y	+ +	Gram - rod	-	Non Vibrio

Key

TCBS = Thiosulphate Citrate bile sucrose agar

+ G = Green, Non Sucrose fermenting Organisms

+ Y = Yellow, Sucrose fermenting Organisms

+ = Positive reaction

- = Negative reaction

+ + + = Profuse growth

+ + = Moderate growth

+ = Scanty growth

From the table above we observe that 3 samples had Vibrio cholerae which causes cholera. Such colonies were oxidase positive, experienced the growth of non sucrose fermenting organisms or greenish colonies, were very motile and had either gram negative curved rod or gram negative rod bacteria. The samples involved here include sample 1 from the Benue, sample 4 from the Chari and sample 7 from the L. C.

All the other samples had non Vibrio, were oxidase negative and not motile and showed the growth of yellowish colonies which indicate the presence of sucrose fermenting organisms. However, the general implication of these results is that there is indication that the water quality from these rivers remains contaminated which can exert a heavy toll on the health of the population.

From the view point of population perceptions on river water quality, this study has shown that out of the 100 respondents interviewed, 67 acknowledge the fact the quality of water in the near by rivers is declining while the remaining 33 simply have no idea of what it takes to conclude that the water is of poor quality.

The common reasons given for this decline are increase population pressure on limited water resources, inadequate access to pipe borne water. The high susceptibility to this declining water quality is inked to the fact that the people have no options and secondly because many of them (33) do not seem to know what low water quality entails.

Generally, the conclusion that can be drawn from this section is that CC and the land use systems such as increase irrigation, deforestation in the midst of population growth in the Northern regions of Cameroon may have worsened the situation of food security and water resource discharge and quality. It has been difficult to attribute the observed deficits to CC entire due to the existing contradictions in the current RF and variability debate. If food production is declining in the Sahel for example and RF is said to be rising as some models hold, what then can be uses to explain the observed trends of decline. As seen in the analysis, the land use systems and population growth come into sphere. Therefore, it becomes difficult to subscribe entirely to CC. This section therefore goes a long way to validate objective 1 and research question 1 of this study on the effects of CC on agriculture and water resources.

4.2 Climate Change, Land use and Population Vulnerability

4.2.1Vulnerability and Gender Main Streaming

This section of this study intends to, based on interviews with the local population, find out the sex that is more vulnerable to food shortages, water shortages and the resultant water borne diseases associated to CC. The IPCC, (2007: 69) and Skeggs, (1997) argue that from a gender stand point, many individuals the world over have unequally or varying capacities to adapt to CC. It illustrates further that woman in subsistence farming localities are disproportionately burdened with the expenses of recovering and adapting to droughts.

The IPCC, (2007: 69) notes that from the point of view of gender, there are individuals and groups within all societies that have insufficient capacity to adapt to CC and its effects. Women involved in subsistence farming are more burdened with the cost of coping and recovering from the effects of CC and land use. There is evidence from empirical research that the elements of adaptive capacity are socially differentiated along the lines of age, ethnicity, class, region and gender. The report argues further that, there are structural

differences between men and women which makes it difficult for them to adapt to the effects of CC. According to the Skeggs, 1997) these differences affect the capacity and ability of women and men to adapt to CC. The report also argues that in most developing countries women are disproportionately involved in natural resource dependent issues as farming when compared with other paid occupations (IPCC, 2007). It is worth mentioning here that the IPCC argues that such resource dependent activities are very often determined by climatic conditions. The IPCC, (2007:730) further comments that changes in climate may affect women in the following ways.

Firstly, it may affect women directly through changes on water availability, fuel wood availability, and vegetation. When these resources get scarce, women are the most affected since they will have to work extra hard or cover longer distances to fetch wood and water.

Secondly, the climate vulnerability of women in agricultural economies is affected by their relative insecurity of access and rights over resources and sources of wealth such as farming land. The argument is that, women are disadvantaged in terms of property rights and security of tenure. The report further holds that this insecurity can have implications both for their vulnerability to a changing climate as well as their capacity to adapt more productive livelihoods in the face of CC.

Thirdly, the vulnerability of women is also associated to the fact that the cultural norms provide for gender discrimination which does not permit women to participate in decision making on issues relevant to their lives.

Writing on the issue of vulnerability to food shortage in the North of Cameroon, Abeh, (2003:22-23) remarks that women in various categories are most vulnerable to food scarcities. Abeh further argues that widows are vulnerable because they have no property rights to land and when their husbands die their land is taken by their in-laws.

The analysis that follows is based on a sample of 100 respondents in the study area. Accordingly, 30 responses were obtained in Kousseri, 30 in Garoua and 40 in the Maroua-Yagoua region. From table 4 below, in Kousseri for example, 28 out of the 30 respondents interviewed acknowledged the vulnerability of the female sex, in Garoua, 29 out of the 30

also acknowledged the vulnerability of the female sex. In Kousseri, 38 out of the 40 respondents consulted also acknowledged the vulnerability of the female sex. The numerators represent the number of respondents that are vulnerable while the denominators represent the total number of respondents belonging to a specific profession The general perception of the interviewees is that women are more vulnerable to the effects of CC. Table 4 is a summary of the responses.

Table 4: Population Perceptions on Female Dominated Vulnerability to climate Change

Professions	**No. in Kousseri that think females are more vulnerable**	**No. in Garoua that think females are more vulnerable**	**No. in Maroua-Yagoua that think females are more vulnerable**
Farmer	13/15	13/13	29/31
Vegetable Vendor	9/9	8/8	2/2
Rice Vendor	2/2	2/2	3/3
Hunter	0/0	0/0	1/1
Teacher	2/2	3/3	2/2
Cattle Rearer	2/2	3/4	1/1
Total	28/30	29/30	38/40

However, according to interviewees what is responsible for this great degree of vulnerability of women? According to information obtained from interviews conducted to the general population, officials of the Ministry of agriculture and Rural Development and Environment and forests the high vulnerability of women is associated to the issues of land rights in the study area. Here, women do not have the power of ownership and control over land. They carry out most of the cultivation yet they do not have access to their output since men control the output as well as own the land.

It was also reported that when a women losses her husband, the relatives of the husband inherit the late man's land thus subjecting the women to more vulnerability. Traditionally, women are responsible for household activities such as cooking, fetching water and fuel wood while the men stray and idle around drinking. This further exposes women to the

effects of CC more directly than men since the free resources upon which they are depending are shrinking. As a result the women need to also work extra hard by covering longer distances to fetch water, wood and get food.

4.2.2Vulnerability and Wealth or Poverty

For this study, the measuring rod for poverty here will be the income levels of the different respondents. This has been compared and correlated with the number of people that acknowledge being affected by any of the effects of CC such as food shortages and diarrheal diseases. Furthermore, the poor are also more vulnerable to water shortages than the rich.

This is because the rich can afford to buy bottled water or pay for pipe borne water while the poor are left to struggle with the poor quality and quantity of water in rivers, Lakes, Ponds and communal wells. Since their purchasing power is low, in times of food shortages they will consequently suffer the most. Extreme poverty exposes Africans to the whims and caprices of CC (IPCC: 2007:48). According to Challinor *et al* (2007), Africa is the most vulnerable continent and less able to adapt to CC particularly due to the poverty of its population. Table 5 and figure 9 that follow summarise the relationship.

From the table below, we observe that as we move from low income to high income the number of respondents affected by any of the effects of CC declines gradually. Therefore, we can say that the lower the income the higher the incidences of effects or the more the people affected while the higher the income the lower are the incidences of the effects of CC. The total number of respondents consulted was 100 of which 97 acknowledged an experience to the effects of CC discussed in this study.

Table 5: Population Perceptions on poverty or Income levels and the number Vulnerable to the Effects of Climate Change

Income Level(Francs CFA)	**No. affected by effects of Climate Change**
5000-20000	39
21000-50000	25
51000-100000	17
101000-200000	09
Above 200000	07
Total	97

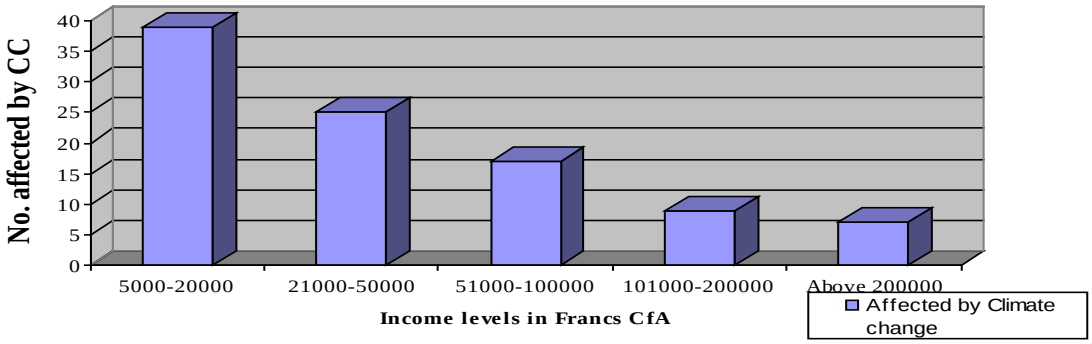


Figure 9: Population Perceptions on Poverty or Income levels and Number Vulnerable to the effects of Climate Change

From the figure above we observe that at a low income level of 5000-20000 FCFA the highest number of those affected by any of the effects of CC is recorded. As the income level however increases towards the right of the chart the number of negative CC experiences decreases. This is explained by the fact that poor people are less able to adapt to the effects of CC than the rich. According to the IPCC, (2007:730) empirical research shows that the elements of adaptive capacity are differentiated along the lines of age, ethnicity, class, region and gender.

From the aforementioned information, this study indicates that different sexes and incomes groups have varying adaptability to the effects of population pressure, land uses and CC. This section of the analysis goes a long way to validate objective 2 and research question 2 of this study.

4.3 Climate Change Adaptations and the Efficiency and Sufficiency of NEMP to Adapt to the situation

4.3.1 Climate Change and Adaptation Measures

Following increasing water Scarcities and food shortages, some adaptation measures have been put in place; these are discussed below and include:

To grapple with the issue of declining discharge and resultant shortage in electricity, a central thermal power plant has been set up in Garoua. This will help supplement the power deficit from Lagdo (CEEPA, 2006:01).

Furthermore, to arrest the problems of variable and unreliable RF and temp, other dams have been constructed on the Logone, Benue, Mayo and Oulo rivers. This has assisted in the generation of hydroelectricity. (CEEPA, 2006: 03).

Population adaptability to declining agricultural production is also enhanced through the use of irrigation. With the declining level of discharge in the region, it is still questionable whether this measure is really adaptive or merely enhancing the problem. This is so because according to CEEPA, (2006:02) dams were set up due to CC with the hope that they were going to retain water but this has aggravated the problem. A case in point is the huge Mega dam on the river Logone which has been responsible for substantial ground water abstraction and has diverted large quantities of water from the L.C.

As concerns livestock farming, adaptations to water shortages and high temp can be possible due to supplementary feeding by fodder, rotation of pasture and altered grazing, development of new heat resistant varieties of livestock (IPCC, 2007:70).

On a long term note, the IPCC, (2007: 111) argues that adaptation can be possible through the planting of trees, commercialising and diversifying livelihoods. This can concretely include involvement in other activities like trade, cattle rearing and increase scholarisation to reduce dependence on agriculture.

However, to enhance adaptation further, it would be wise for Africa to be more involved in CC negotiations and to benefit accordingly. According to Araya, Araya (2009) and Cornelis, (2004), even if Africa is the most affected region yet it has gained very little or least from CC negotiations. Araya (2009) holds further that, enhancing adaptive capacities in Africa will include action at the level of the global community to see that Africa gets the funding required to adapt adequately to CC. This will enhance investments in genetically modified organisms (GMO) though it is argued further that unproven and unpatented GMO'S will not help the southern countries adapt to CC because it is not yet sure how these plants will perform in the field (Araya 2009).

Other possible methods of adaptation include improving water use efficiency by indigenous water harvesting of scarce precipitation from larger less productive zones to smaller areas where commercially viable crops, shrubs, trees can be grown under normal prohibitive amounts of RF (Thomas *et al* 2008). This may also be achieved through systems of irrigation such as the sprinkler and drip irrigation which are more efficient in the use of water, in areas where about 95 percent of water withdrawal is used for agriculture, simple methods such as a move from the wasteful surface furrow irrigation to alternate furrow irrigation can result in huge water savings of up to 30 percent and yields increases of 15-20 percent as is the case in Kazakhstan (Thomas *et al* 2008).

On the issue of mitigation to CC, the 100 respondents interviewed, 59 percent propose increased reforestation, 23 percent propose reduced bush burning, 10 percent propose provision of pipe borne water and 08 percent propose the digging of wells as the different ways of mitigating the effects of CC. From this analysis, it becomes clear that deforestation is very severe in the area, and its main effects have been enhanced environmental degradation.

Concerning adaptation, the responses were as follows: livestock diversification (03 percent), new crops (18 percent), construction of dams (28 percent) have already been put in place. The responses show that they will generally prefer diversification of livelihoods (51 percent) in the areas of investments in trade in the midst of dropping agricultural output. To enhance this, they propose that, government and local and international NGOs need to put a funding mechanism to support this scheme.

However, semi-structured interviews with three officials in the ministries consulted opt for adaptation. They do not however reject mitigation but argue that mitigation is long term and the ideal but since man is hardly ideal both measures should be put in place. To them, concrete adaptation measures will address recurrent effects of CC while mitigation would mean eradicating CC which is next to impossible in the short run.

4.3.2 The Efficiency and Sufficiency of NEMP

In 1996 the government o Cameroon came out with the National Environmental Management Plan (NEMP). Concerning the Sudano-Sahelian region to which part of this

study area belongs NEMP has proposed the following specific measures to halt environmental degradation.

The link between the NEMP and the millennium development goal number one is established when the NEMP argues that with regards to most developing countries in general and especially sub-Saharan African countries, the African common stand on agenda 21 is that poverty is a major, if not the most harmful cause of environmental degradation(UN,2005). According to NEMP, (1996:03-04) poverty remains the main cause of environmental degradation that causes water scarcities and food shortages. The plan attributes the problem of environmental degradation to poverty and recommends poverty alleviation but unfortunately it does not in anyway show how poverty can be concretely eradicated.

The government of Cameroon has since the 1990s been involved in a poverty alleviation struggle but the situation seems to remain stagnant. Ajaga (2004: 212,) notes that the plan of the government to eradicate poverty has targeted the wrong civil society groups. This is evident as current interest is towards improving the situation of civil servants while the poor masses languish in abject poverty.

Being that Cameroon is an agrarian economy, this study proposes that NEMP would have been more effective if an agenda to target the most vulnerable populations such as women was put in place. NEMP is thus too vague on the solutions to poverty alleviation. According to NEMP (1996: 14), poverty is as a vicious cycle and is both the cause and effect of environmental degradation (Lambi, 2001). If this is true, the plan would need to have taken some concrete steps to meet up with some of the needs of agrarian populations in the Far North. Such concrete steps would include provision of mechanisation, fertilizers, expert advice and other farm implements at low interest rates and corruption eradication. An open access to markets for their products to ensure a stable price would also help to assure the farmers of steady incomes (Bunyui, 2006: 61-62).

These second set of measures outlined by the plan are steps in the right direction. However, they constitute long term measures whose effects can mostly be seen in the long run from sustained effort (IPCC, 2007:111). Also, these measures need to be very concrete and

backed up with long term strategic plans as well as support from all political levels including reducing corruption.

A careful identification of stakeholders and their participation to create a more balanced system of empowerment along the lines of gender equity as highlighted by the millennium development goals number two and three would also help reduce vulnerability (UN, 2005). NEMP is however very constructive at this point and it identifies a complete synergy when it argues that, NEMP (1996:06) only a global approach that brings in all stakeholders can solve the problems of environmental management which are multisectorial because they affect all sectors of the national economy. This calls for increase cooperation of the entire civil society-ministries, the private sector, trade associations and NGOs.

The NEMP is unclear on who constitutes the civil society among the stakeholders. In this way the proposal is weakened by its inability to bring in poor masses into the framework. This current study therefore proposes that the poor masses, local farmers and women who are the main sufferers of the effects of CC be involved, if this is not done, then, the local realities of the area will not be taken into consideration and there may be no positive outcomes.

The NEMP also highlights the role of international cooperation to involve neighbouring countries. This is particularly important because one of the water masses most threatened is the L.C and this lake straddles three countries which are Chad, Cameroon and Nigeria. Such transboundary co-operation has been concrete through for example the implementation, ratification and active participation in the activities of the L.C basin commission.

The NEMP is particularly silent on the systems of adaptation. This study notes that the adaptive capacity is dynamic and strongly linked to economic, natural and social networks, entitlements, institutions, governance, human resource and technology. For example, research in the Caribbean on hurricane preparedness shows that appropriate legislation is always necessary before the implementation of plans for adaptation to future and present CC (IPCC, 2007: 69). For a legislation to be appropriate it needs to be adapted to the local

institutional context as well as to the perceptions and wills of the population that actually may inflict any changes, in this case the local population.

Unfortunately, NEMP has no outline of adaptation measures neither for the national nor for the local level, which could be put in place to meet up the challenges of CC. As such, in the face of droughts as was the case in the 1970s in the study area, vulnerability increases and the cycle of hardship was enhanced CEEPA, (2006: 01).

Furthermore, NEMP is also silent on vulnerable groups. This is important since different ages and sexes respond differently to CC. Since women are more vulnerable, a clause to protect the interest and reduce the vulnerability of these needs to be put in place. It is the proposal of this study that the revised plan has to take into consideration.

It is also agued that, one reason why the government of Cameron is seen as unable to manage environmental degradation is because the state lacks the means to manage the environment and therefore often has to be indifferent to overexploitation of resources to cope with its obligations such as foreign debt and functioning of the state etc. This illustrates that poverty at all levels of national life is focal in issues of implementation of the measures outlined in NEMP (NEMP 1996:04).

At research time in February 2009, 13 years after the plan was drawn it was being updated. An official interviewed in MINEF held that the plan was supposed to have been revised every 5 years but problems of governance and the fact that the administration in place hardly stays in office to fully execute its goals causes this target to be missed. However, a new study is underway and its report will form the basis of the revised NEMP. From the above loop hole, it becomes more understandable, why the NEMP has lots of weaknesses as seen above and has done very little to handle these problems in terms of concrete implementation and policies.

4.3.3 Population Perceptions of the NEMP

In this section, the study shall assess the knowledge and views of the NEMP of the interviewed segment of the population. Of the 100 hundred respondents contacted a total of 94 acknowledged knowing about NEMP while 93 said NEMP has not been a success. Of all these respondents only one rice vendor thought the plan was successful.

The common reasons why the respondents think NEMP is not a success includes the fact that their agricultural output keeps declining, water resources dry up and women and the poor masses are the essential precursor of these. According to officials in the Ministries of Environment and Forestry (MINEF), Agriculture and Rural Development and Mines water and Power, the problem is related to the short term periods of each administration where nothing is done until it is time to restart the election campaigns, budget constraints, the current economic crisis facing the country and inefficiency and corruption of some officials at all level which leads to misappropriation of funds. Table 6 below summarises these population perceptions discussed above.

Table 6: Populations Perceptions of NEMP

Professions	No. that report to know about NEMP	No. that report that NEMP is not been a success
Farmers	55	55
Vegetable vendor	17	17
Rice vendor	7	6
Hunter	1	1
Teacher	7	7
Cattle rearer	7	7
No ideas answers	6	7
Total	94	93

This section of the analysis goes a long way in assisting in the substantiation of objective three and research question three on adaptations and the efficiency and sufficiency of NEMP to enhance adaptation.

Chapter 5
Conclusions and Recommendations

5.1 Conclusions

This study has found out that temp increase and declining RF and land use patterns in the Sahel of Cameroon are worsening the recorded rates of decline in agricultural output. This has also worsened declines in river flow or discharge and indirectly caused the quality of river water to decline. The evidence of the latter is because due to CC, irrigation, deforestation and population growth there is increase pressure on scarce water resources with a resultant increase in pollution. The conducted chemical analyses reveal the presence of several pathogens while a majority of the respondents also accept the fact that the water is contaminated.

Furthermore, the study has shown that increase vulnerability to the effects of CC is along the lines of gender and poverty with females and the very poor masses being the most vulnerable to these effects. From a management perspective, the NEMP of 1996 is inadequate and in sufficient to handle adaptation to the crisis while existing adaptation measures put in place are also in sufficient, thus a proposal of other possible measures.

However, these results are a reflection of the situation based on population perceptions and official records. A larger sample size, more willingness by the officials and respondents to provide more information on the state of the situation and a readily available secondary data archive on CC repercussions in Cameroon would have even made these results better.

5.2 Recommendations

Based on the findings of this study, the following recommendations have been made:

Firstly, to better subvert the issue of food shortages, it will be necessary to meet the needs of the farmers in the lines of farm tools, fertilizers and extension advice from the National Agricultural Extension service. The above will reduce cost of production and enhance output. This could be a form of government sponsored capacity building programme under which farmers can be assisted financially to increase crop production (Mani *et al*, 2008:05).

The above could be complemented by a government policy towards stabilization of prices of agricultural products. This will only be possible if the current policy deficits in the areas of insufficient implementation and incompetent human resources be changed.

In the area of declining water quantity and quality, this study calls for the provision of pipe borne. This means that water obtained from the three major rivers (Benue, Chari and Logone) should be well managed and other minor streams harnessed. This means that the Cameroon water utility corporation (CAMWATER) has to harness other streams and secondly by increase its facilities in an attempt to provide more water. At an individual level, the indigents of most of the neighbourhoods can reduce the possibilities for cholera outbreaks by observing personal sanitation, boiling their river water before consumption, avoiding road site drinks and food.

However, the above measure shall not be effective if the cost per cubic meter of water is not made affordable. This is because a majority of those affected by the effects of CC are poor and may not be able to pay for very expensive pipe borne water.

To reduce the level of population vulnerability, poverty reduction in the lines of population empowerment through loans to enable farmers diversify their livelihoods should be put in place. The degree to which poverty can be reduced in the study area in particular and in other parts of Cameroon depends on a perfect mix between the will and commitment of leadership, the rational use of resources and the participation of the people in the decision making process. Unfortunately, extant policy frameworks in Cameroon are regrettably both fragmented and fragile. This deters sustained efforts in the alleviation of poverty. To achieve this in the study area, the voices of the poor recorded from the questionnaires used during fieldwork indicate that sound policy dialogue cannot be attained without genuine efforts to invest ownership building, institutions and the participation of the population on the basis of their needs and priority.

Concerning the issue of NEMP, the MINEF should incorporate a section that handles CC and the specific causes, adaptation and mitigation measures to be used with the Sudano-

Sahelian region. The adaptation could follow the following pattern as discussed by Mani *et al* (2008:03).

- Response to current variability
- Observed medium term and long term trends of CC
- Anticipatory planning in response to model based long term scenarios of CC

This study also proposes that other studies be carried out in the area of long term scenarios based on an anticipatory planning and alternative action. This therefore calls for the governments to initiate a funding mechanism in collaboration with various NGO's, International organisations and funding financial institutions. This will invariably create awareness and enhance adaptation.

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Appendices

Appendix 1: Questionnaire

Lund University

International masters in environmental and sustainability sciences

Questionnaire for the General Public in Kousseri, Maroua and Garoua

Dear Respondent,

I am a master's student from the above university and faculty. I am currently carrying out Research on the topic:

The Effects of Climate Change on Water and agricultural Resources in the Sahel of Cameroon: Population Vulnerability, Adaptation and Management Options

I shall be grateful if you can help me fill this Questionnaire, I promise that the information provided will remain strictly confidential and will be used only for research purposes.

Yours Faithfully

Epule Terence Epule

[ ] Identification Number

Place of Residence……..

Section1: Evaluation of Water and food scarcity and Impact.

Please tick, write or underline the right answer where necessary.

Sex and Marital status?

Female

Male

Married

Widow

Do you have children? Yes No

If Yes how many? .....

How many lives at home? .....

What is your profession?

	Farmer
	Vegetable Vendor
	Rice Vendor
	Hunter
	Teacher
	Cattle rearer
	Others, Specify here,

What is your approximate monthly income in francs CFA?

	5-20000
	21000-50000

	51000-100000
	101000-200000
	Above 201000

Is there pipe borne water in your house? Yes ☐ No ☐

If No, where do you get water for drinking?

Wells | Streams | Lake | Others, specify below

……..

……

……..

Is your supply of water regular?

Yes | No | Others, specify below

……..

If no, what is the main cause of this irregularity?

……

……..

What are the main effects of the irregular water supply on your life?

Fall in agricultural output

Drop in fish out put

Irregular HEP (Hydroelectricity power)

Water borne disease

Other, specify

……..

What can be done to improve on the situation of water shortages in your area?

Provision of pipe borne water

Digging of wells

Reforestation

Reduced bush burning

Others, specify

……

What systems of adaptation to lack of water can be put in place? Please specify where necessary.

Adaptation	Specification	Responsible for action
Diversification of livelihoods		
Construction of dams		
Introduction of new crops		
Livestock intensification		
Others, Specify		

Who do you think is responsible for taking action? Specify for each adaptation on the table above.

13) Which of these actions could be beneficial for you directly?

……

14) What could be your part in taking action?

……

Section 2: Evaluation of Standards of living, Vulnerability and NEMP

Please tick, write or underlines the right answers were necessary.

1) a) Which sex do you think is most affected by water and food

Shortages?

-Male -Female -Female widows - Male widowers

- Others, Specify…….

b) Why? .....

c) What can be done to reduce this problem? .....

……..

2) a) Which age group is most affected by water and food shortages?

Young children - Adult men - Adult women

- Others, Specify…….....

b) Why? ……

c) What can be done to reduce this problem?

……

3) What do you think can be done to reduce vulnerability to food and water shortages? .....

4) Do you know about NEMP? Yes No

5) If yes has it been a success? Yes No

6) Why Yes or Why No? .....

Appendix 2: Interview Guide

Lund University

International masters in environmental and sustainability sciences

Interview guide for Officials in the Ministries of Agriculture, Mines, Water and Power, and Environment and Forest

Dear Respondent,

I am a master's student from the above university and faculty. I am currently carrying out Research on the topic:

The Effects of Climate Change on Water and agricultural Resources in the Sahel of Cameroon: Population Vulnerability, Adaptation and Management Options

I shall be grateful if you can help me answer the questions that follow, I promise that the information provided will remain strictly confidential and will be used only for research purposes.

Yours Faithfully

Epule Terence Epule

What position do you hold in your Ministry? .....

Are you aware of the occurrence of climate change in the north of Cameroon

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What are the main causes of Climate Change in the above area? .....

What are the main indicators of the effects of climate change on agriculture and river discharge?.....

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From your records, which sex and wealth groups are more vulnerable to the effects of climate change? .....

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Why is the sex and wealth group you have selected above more vulnerable? .....

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What role has the National environmental management plan played in solving the crisis?

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Do you classify the National environmental management as a success?

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If yes or no to the question above, give a reason why ……

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What adaptation measures have been put in place to address the situation, if Non what do you suggest?

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Has climate change in anyway resulted in declining water quality?

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If yes to the question above give a reason for the situation.

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Is there any other information you would like to give me on the situation of climate change in the region?

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