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CLIMATE VARIABILITY IMPACTS ON MAIZE PRODUCTION AND FOOD SECURITY IN BAMENDA II SUB-DIVISION, NORTH WEST REGION, CAMEROON

A Master's degree in Geography dissertation defended on the 26 July 2023

SPECIALTY: ENVIRONMEMTAL DYNAMICS AND RISKS

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DEDICATION

To the Akombo’s family

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This work could not have been realized single handedly; it involved collective effort of individuals and institutions who showed me their love and care in this academic write-up that I would love to appreciate

.

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ABSTRACT

Climate variability has negative effects on rain-fed crop production systems, especially staple crops like maize, leading to threats to food security in rural, semi-urban and urban areas in the tropics. This study, therefore, sets out to climate variability impacts on maize production and urban food security in Bamenda II Sub-division. The work is guided by the hypothesis that variation in rainfall and temperature does not significantly affect maize production. Data was sourced from primary and secondary sources. Primary data entailed the administration of questionnaires in the main agricultural zones of Chomba, Nsongwa, Mbatu, Mulang, Ntankah and Mukwebuh, while secondary sources included mean rainfall and temperature data from the North West Regional Service for Meteorology. The data was processed using descriptive and inferential statistics. The results revealed that the magnitude of climate variability is high (46.2%). The dependable sources of climate information are radio and television with values of 41.5% and 33.3% respectively. Recent changes in climatic dynamics include increasing temperatures, oscillations in the onset of the first rains and cessation of the wet season, increasing incidence of wind on agriculture, human settlements and urban infrastructure. Meteorological data indicates that the inter-annual rainfall trend is decreasing, while the inter-annual temperature is increasing. Again, the trend of the growing season has been evaluated using the Cumulative Departure Index (CDI), showing a decreasing trend. Rainfall reliability (Coefficient of Variation-CV) shows that the trend has increased from 10.69% in the decade 1963-1972 (reliable) to 25.91% during the period 2013-2021 (unreliable). The CV is complemented by the Standardized Precipitation Index (SPI), which shows a decreasing trend with recurrent meteorological, hydrological and agricultural droughts. Adaption to climate variability to ensure food security takes into indigenous and conventional strategies. Farmers employ agro-forestry, micro-irrigation schemes (dry season), indigenous soil and water conservation, alteration of planting dates, as well as use of improved planting materials. The success of these strategies is possible with sustainable livelihood assets. The social, natural and human capital assets are available, but financial and physical capital assets are scarce. These acts as constraints to adaptation to climate variability to ensure food security. There is need to protect the environment against human activities that affect the rainfall pattern especially those activities contributing to climate variability. The understanding of the relationship between climate and agriculture will enable farmers to fit crops to climate and avoid unpleasant consequences of agricultural planning and development.

Key words: Climate, variability, food security, impacts, maize, Bamenda II

RESUME

La variabilité climatique a des effets négatifs sur les systèmes de production de cultures pluviales, en particulier les cultures de base comme le maïs, menaçant la sécurité alimentaire dans les zones rurales, semi-urbaines et urbaines des tropiques. Cette étude vise donc à déterminer les impacts de la variabilité climatique sur la production de maïs et la sécurité alimentaire urbaine dans la subdivision de Bamenda II. Le travail est guidé par l'hypothèse selon laquelle la variation des précipitations et de la température n'affecte pas significativement la production de maïs. Les données proviennent de sources primaires et secondaires. Les données primaires ont consisté en l'administration de questionnaires dans les principales zones agricoles de Chomba, Nsongwa, Mbatu, Mulang, Ntankah et Mukwebuh, tandis que les sources secondaires comprenaient des données sur les précipitations et les températures moyennes provenant du Service Régional de Météorologie du Nord-Ouest. Les données ont été traitées à l'aide de statistiques descriptives et inférentielles. Les résultats ont révélé que l'ampleur de la variabilité climatique est élevée (46,2%). Les sources fiables d'informations climatiques sont la radio et la télévision avec des valeurs respectives de 41,5% et 33,3%. Les changements récents dans la dynamique climatique comprennent l'augmentation des températures, les oscillations dans l'apparition des premières pluies et la fin de la saison humide, l'augmentation de l'incidence du vent sur l'agriculture, les établissements humains et les infrastructures urbaines. Les données météorologiques indiquent que la tendance interannuelle des précipitations est à la baisse, tandis que la température interannuelle est à la hausse. Là encore, la tendance de la saison de croissance a été évaluée à l'aide de l'indice de départ cumulé (IDC), qui montre une tendance à la baisse. La fiabilité des précipitations (Coefficient de variation-CV) montre que la tendance a augmenté de 10,69% dans la décennie 1963-1972 (fiable) à 25,91% au cours de la période 2013-2021 (non fiable). La CV est complétée par l'indice de précipitation standardisé (SPI), qui montre une tendance à la baisse avec des sécheresses météorologiques, hydrologiques et agricoles récurrentes. L'adaptation à la variabilité climatique pour assurer la sécurité alimentaire prend en compte les stratégies indigènes et conventionnelles. Les agriculteurs ont recours à l'agroforesterie, aux systèmes de micro-irrigation (saison sèche), à la conservation des sols et de l'eau, à la modification des dates de plantation et à l'utilisation de matériel végétal amélioré. Le succès de ces stratégies est possible grâce à des moyens de subsistance durables. Les capitaux sociaux, naturels et humains sont disponibles, mais les capitaux financiers et physiques sont rares. Ces facteurs constituent des contraintes à l'adaptation à la variabilité climatique pour assurer la sécurité alimentaire. Il est nécessaire de protéger l'environnement contre les activités humaines qui affectent le régime des pluies, en particulier celles qui contribuent à la variabilité du climat. La compréhension de la relation entre le climat et l'agriculture permettra aux agriculteurs d'adapter les cultures au climat et d'éviter les conséquences désagréables de la planification et du développement agricoles.

Mots Clés : Climat, sécurité alimentaire, variabilité, impact, mais, Bamenda

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LIST OF ABBREVIATIONS AND ACRONYMS

ANOVA: Analysis of Variance

BUCREP: Central Bureau of the Census and Population Studies

CDI: Cumulative Departure Index

CDP: Council Development Plan

CIG: Common Initiative Group

CO_2: Carbon dioxide

CRTV: Cameroon Radio and Television

CRTV: Cameroon Radio and Television

CV: Coefficient of Variation

EGS: Early Growing Season

EGS: Early Growing Season

FAO: Food and Agriculture Organization of the United Nations

GEC: Global Environmental Change

GHGs: Greenhouse Gases

HFA: Hyogo Framework for Action

HFIAS: Household Food Insecurity Access Scale

IPCC: Intergovernmental Panel on Climate Change

IPRCC: International Political Response to Climate Change

IRAD: Institute for Agricultural Research and Development

ISDR: International Strategy for Disaster Reduction

LGS: Late Growing Season

LGS: Late Growing Season

MINADER: Ministry of Agriculture and rural Development

MINEPDED: Ministry of Environment, Nature Protection and Sustainable Development

NCCAP: National Climate Change Action Plan

NCCRS: National Climate Change Response Strategy

NGO: Non-Governmental Organization

SD: Standard Deviation

SI: Seasonality Index

SPI: Standardized Precipitation Index

SSA: Sub-Saharan Africa

TV: Television

UNFCCC: United Nations Framework Convention on Climate Change

UNISDR: United Nations Office for Disaster Risk Reduction

USA: United States of America

WMO: World Meteorological Organization

WMO: World Meteorological Organization

GENERAL INTRODUCTION

0.1 The Research Context

Scientists have been tasked in coming up with a global response to this global challenge termed as climate variation by various climate change bodies. The global surface temperatures in the last three decades and past century have warmed up by 0.6°C and 0.8°C respectively (Hansen et al., 2006). In 1992 the International Political Response to Climate Change (IPRCC) began with the ratification of the United Nations Framework Convention on Climate Change (UNFCCC).Stabilizing the greenhouse gases concentration in the atmosphere at a threshold that would avert severe anthropogenic interference with the present climatic systems in our world was the main purpose of the convention (IPCC, 2001). This led to the signing of the Kyoto protocol of 1997 committing countries towards taking up climate action. According to the National Climate Change Action Plan Report-NCCAP (2013), climate variation can be monitored through measurement of the climatic elements such as wind, atmospheric pressure, temperature and rainfall among others (United Nations Development Programme, 2013).

Studies carried out by IPCC have pinpointed Africa to be one of the most exposed continents to suffer the devastating effects of climate change and climate variability, with colossal economic impacts due to inadequate adaptive capacity. The African rain-fed agriculture is viewed by many observers to be the most vulnerable sector to climate variability and the potential impacts of climate change on agriculture are highly uncertain. According to the World Meteorological Organization-WMO, (2018) the overall global warming is expected to add in one way or another to the difficulties of food production and scarcity. The report also stated that reduced availability of water resources would pose one of the greatest problems to agriculture and food production, especially in the developing countries. Also, Katz and Brown (not dated) reported that climate variability is likely to increase under global warming both in absolute and relative terms.

According to reports of IPCC, factors such as endemic poverty, bureaucracy, lack of physical and financial capital, frequent social unrest and ecosystem degradation contribute to Africa’s vulnerability to climate variability. Almost 60% of the population of Cameroon is rural-based with livelihoods predominantly dependent on subsistence crop farming and/or livestock rearing. Over the past years, multiple interrelated factors such as small fragmented landholdings and minimal access to agricultural inputs, reduced employment opportunities, market inefficiencies have contributed to chronic food insecurity and gradually weakening livelihood. In addition, the agricultural system is dominated by a single crop, which is maize, coupled with the extensive dependence on rain-fed agriculture which will further increase households' vulnerability due to erratic rainfall and weather variability. Minimal shocks to agriculture therefore have a profound impact on the ability of rural households, especially the chronically poor, to maintain their food security. Climate change and variability is clearly evident in Cameroon as it manifests itself in various hydrological disasters.

Agriculture in Cameroon depends on rainfall to a very large extent and the activities in the dry season are less affected by climate change than in rainy season. Since the 1990s, crop production in Cameroon like maize has faced the negative impacts of extreme climate events, believed to be manifestations of long-term climate variability. Bamenda II has experienced some of its worst droughts and floods in the last two decades whilst significant rainfall deficits/cessation at critical stages of crop growth has frequently led to a serious fall in crop production especially maize. According to the 2004/2005 crop and Food Supply Assessment, virtually all areas in Bamenda II consume maize, either fresh or processed. Maize is a major ingredient in infant food brewery and poultry feed industries. It is also fermented to produce hydrolyzed dextrin, sugars, and syrup. Specifically, maize is a hot season crop and is grown principally in areas with temperatures range of 21-30ºC, though seeds germinate best at a lower temperature range of 18-21ºC. Adequate rainfall or water is very important during germination and the first month of growth.

0.2 Delimitation of the Research Topic

0.2.1 Thematic Delimitation

The main themes in this research are climate variability (temperature and rainfall), maize, and food security (food availability, food safety, food accessibility and food utilization). These elements have been assessed, monthly, annually or decadally. Climate variability has been assessed using basic measures of central tendencies, such as Standard Deviation (SD) and Coefficient of Variation (CV). These measures form the basis for assessing reliability of climatic elements for crop production. According to the Inter-governmental Panel on Climate Change (IPCC,2001),“climate change refers to a change in the state of the climate that can be identified (using statistical tests) by changes in the mean and/other variability of its properties, and that persists for an extended period, typically decades or longer”. It may be any change in climate over time, whether due to natural instability or as a result of human activity. This definition differs from the definition of the United Nations Framework Convention on Climate Change (UNFCCC), where climate change refers to a change of climate that is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and that is in addition to natural climate variability observed over comparable time periods. Climatic variability can be considered as a component of climate change. According to the IPCC (2007), climatic variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

Measuring climatic variability involves evaluating the gap between the achievements of the climate variable (rainfall or temperature) and its equilibrium value. This equilibrium value refers to the existence of a permanent state or trend. Generally, we measure climatic variability by the standard deviation or the average deviation in absolute value of the distribution of a variable, relative to its mean or to its long-term trend. The standard deviation weights the extreme events more strongly than the average deviation**.** Other indicators of climatic variability may be the variation. Coefficient, the kurtosis coefficient and the asymmetry coefficient. The kurtosis coefficient and the asymmetry coefficient (skewness coefficient) are respectively the three-order and four-order moments and obtain information about climatic variability of countries and particularly the frequency of the extreme events.

Temperatures

Cameroon offers an almost complete range of inter-tropical climates. The varied relief and the proximity of the ocean also introduce gradations due to the effects of the mountains and the sea. The mean temperatures are high and vary little during the course of the year. They increase from south to north, decrease with altitude and vary between 20°C at Dschang at

1,400 meters above sea level and 28°C at Garoua in the north. There is little variation between day and night temperatures except in the north. The amount of sunshine varies in the same way. In the equatorial zone, it is lowered by the amount of rainfall, the relative humidity and cloud cover (Etia, 1973).

Rainfall

Rainfall in the forest zone is between 3,000 to 4,500 mm per year. At the foot of Mount Cameroon and along the coast the rains are heaviest. There is precipitation almost throughout the year. The rest of the forest zone has two rainy and two dry seasons per year. The first rainy season is from March to mid-July and the second from mid-August to November, while the unreliable August break is from mid-July to mid-August. The second dry season is from mid-November to end of February. The forest zone is further divided into the humid and semi-humid forests. Two maize crops per year are planted during the rainy seasons. However, very often farmers around the big urban centers (Yaoundé and Douala) start planting when sporadic rains begin in January/February and continue till end of September or plant in swampy lands during the dry season.

0.2.2 Food Security

Food security is referred to as a state when: “all people at all times, have both physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life,” (FAO, 2010). On the other hand, food insecurity is a state when food is not easily accessible to households and they are facing difficulties in securing sufficient and nutritious food (Wakibi et al., 2015). Food insecure households are those that do not have both economic and physical access to food and this may be due to inadequate food, low purchasing power and poor usage of food at household level (Icheria, 2015). The four components of food security are stipulated as: availability, access, utilization and stability.

0.2.2.1 Food Availability

Food availability plays a very important part in food security. It refers to the production, distribution, and exchange of food in appropriate quality for people to meet basic food needs and this can be supplied through household's own production or import (FAO, 2015).

0.2.2.2 Food Accessibility

Food accessibility is referred to as a household's capacity to access food of the needed quantity, quality, and nutritional type through production, purchase, gifts, borrowing or aid. Food access is directly associated with a household's financial ability to afford needed food for an active and healthy life (FAO et al., 2015).

0.2.2.3 Food Utilization

This is the ability or capacity of the household to utilize essential food nutrients from the food they consume or access (FAO, 2008). Utilization includes the nutrient content of the diet that is, how well food is utilized and whether the diet is well balanced with adequate nutrients (Chauvin, 2012).

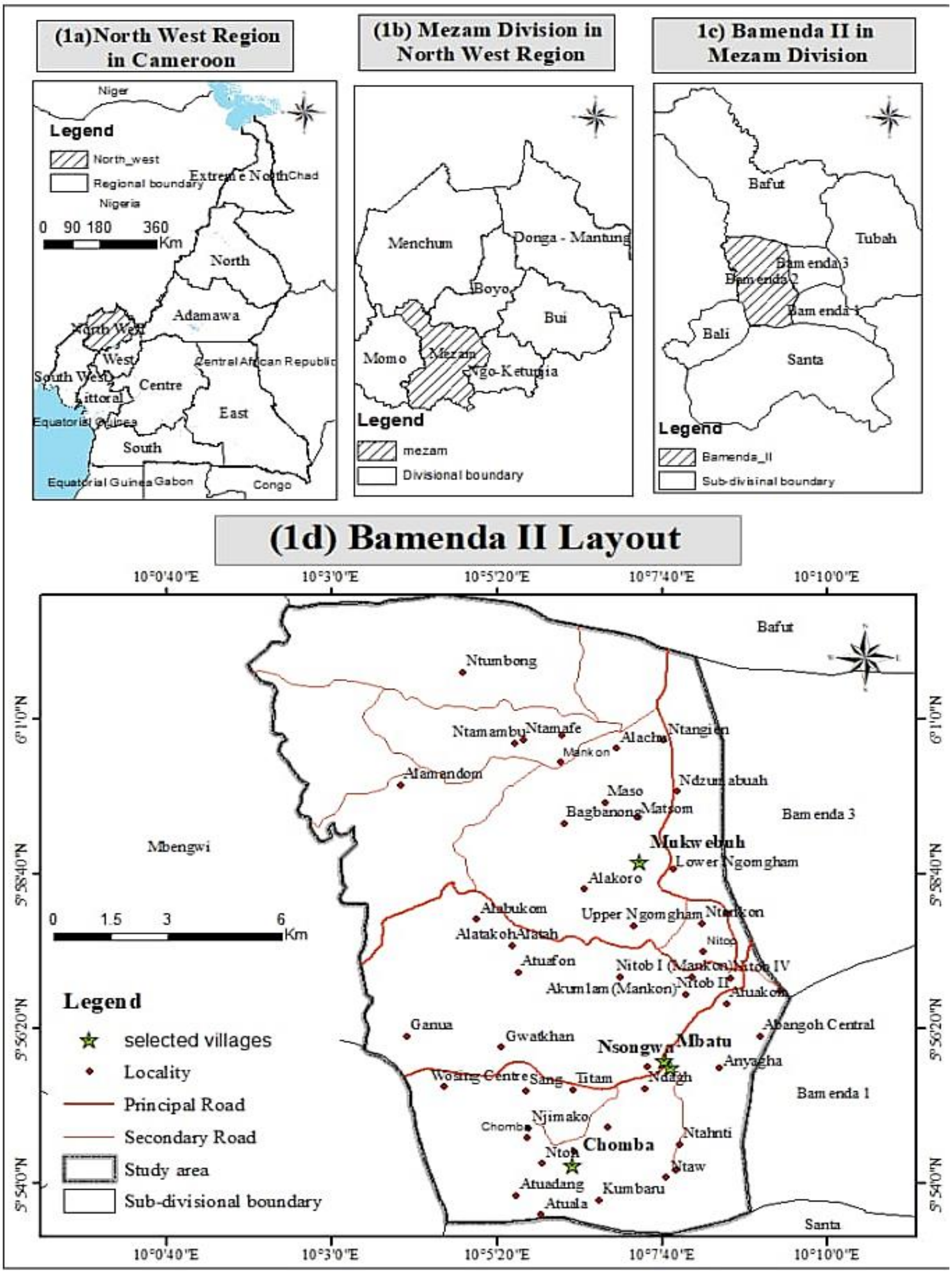
0.2.2.4 Food Stability

It is determined by the availability and access to food. Stability supports availability, access and utilization as well as captures the level of uncertainty or susceptibility to future commotions in food security. For instance, food chains, processing, storage, marketing and distribution constitutes the integral, methods that have preserved the food system from instability (Bunyasi, 2012). Risks to stability include climatic conditions, conflict, price shocks, production and supply, swing in food and input prices and disease, among other factors (FAO et al., 2013).

Agriculture in Cameroon depends on rainfall to a very large extent and the activities in dry season are less affected by climate change than in rainy season. Since the 1990s, crop production in the country especially of maize has faced the negative impacts of extreme climate events which are believed to be manifestations of long-term climate variability. Bamenda II has experienced some of its worst droughts and floods in the last two decades whilst significant rainfall deficits/cessation at critical stages of crop growth has frequently led to a serious shortfall in crop production especially maize. According to 2004/2005 crop and food supply assessment, virtually all areas in Bamenda II consume maize, either fresh or processed. Maize is a major ingredient in infant food brewery and poultry feed industries. It is also fermented to produce hydrolyzed dextrin, sugars, and syrup. Specifically, maize is a hot season crop and is grown principally in areas with temperatures range of 21-30ºC), though seeds germinate best at a lower temperature range of 18-21ºC. Adequate rainfall or water is very important during germination and the first month of growth. It is argued that this study is of relevance because it indicates the differences in climatic elements (average annual temperature and rainfall) and agronomic factors required for maize production (maize hectare and output) in different zones of Bamenda II. The production of the country's staple food, maize was on a long-term decline, dropping by 70% over a period of five years in most areas. This was due to non-cultivation of the arable lands due to delayed rainfall and the high risk of making loss from agriculture as well as shortage of seeds for alternative crops among other. Bamenda II has suffered below average and declining cereal production as a result of erratic rainfall patterns, which are exacerbating the impact of rising unemployment and increased poverty. The purpose of this study is to analyze the impacts of climate variation challenges on maize production and food security in Bamenda II.

0.3 Spatial Delimitation

Bamenda is the headquarter of the North West Region of Cameroon. Bamenda and lies between latitude 5^{o}56N and longitude 10^{o},10E (Figure 0.1).Bamenda II is bordered, in the North by Bafut Sub-division,in the East by Bamenda I and III Sub-division, in the South by Bamenda IISub-division, and in the west by Bali Sub- Division. The city has a population of about 2 million people and is located 366km north-west of the Cameroon's capital, Yaoundé. Bamenda II is known for its cool climate and scenic hilly location.



Source: Bamenda City Council, 2015

Figure 0. 1.: Location of Bamenda in the North West Region of Cameroon

0.4 Temporal Delimitation

Available climatic data for this study spans to 1963 to 2021 for rainfall and 1975 to 2021 for temperature. This is anchored on the fact that Bamenda II experienced a significant rate of urbanization and urban development during this period. As a result, the need to produce more food to feed the ever-growing population became a condition sine-qua-non. Also, the economic crisis that hit Cameroon in the late 1980s and the devaluation of the CFAF contracted public investments and pushed the state to disengage itself from urban development and management. Instead of devaluation acting as a problem-solving policy, it worsened the livelihood of Cameroonians in general and Bamenda in particular as prices of imported goods doubled, inflationary price increased, loss of competitiveness of traditional export crops on the world market, inefficiency in the production system were the outcomes. This has negative repercussions on the population as the increase in prices of goods was not counteracted by a substantial increase in the purchasing power of the people in Bamenda II. Inhabitants of Bamenda were forced to turn to agriculture of which the cultivation of maize constituted an important part since then to present.

Bio-physical milieu

Bamenda II Council is endowed with enormous resources and potentials (Table 1.1). The analysis of the natural sites brings together the characteristics (assets, potentials and threats) of different features and various components of the natural site for planning purposes.

Table 0.1: Assets, potentials and constraints of biophysical milieu of Bamenda II

Feature	Assets	Potentials	Threats
Climate	Cold tropical climate	Has a dry and a rainy season	- Too windy - Torrential nature of rainfall - Heavy leaching of soils
Soils	Volcanic soils available	Contain black quarries and laterite pits used for construction	Heavy leaching around hill slopes
Vegetation	Forest, woodland and regrowth savannah	Eucalyptus tree used for construction, electricity poles and as local fuel	- Unsustainable management of forest resources - Biodiversity loose

Relief	Topography is undulating with some steep slopes	Rich varied topography are main touristic sites	Topography causes difficulty in farming
Hydrology	Available water bodies like streams, and small waterfalls	- Source of water for domestic use - Touristic site	- Unsustainable management of water resources - Water pollution
Protected areas	Shrines	- Touristic sites - Preserve the cultural heritage	Their values are fading away
Mineral resources	Stoney and sandy soil	- Quarries for black stones used for construction - Sand	Poor management of these resources

Source: Bamenda II Council, 2020

Human milieu

Bamenda is made up of virtually all the villages which formerly made the Bamenda Central Sub-division and all the villages of Bamenda I, II and III Council areas. As the regional headquarters, Bamenda offers the population and the entire region, administrative, commercial and social services. These functions are unprecedented since its creation which dates back to the construction of the "Ford" by the Germans in the 1900. Bamenda was created to control the territory and to introduce a modern administration into an environment which was strongly structured along the lines of customary law. The dialectic position (the Ngemba dialect in particular) gave rise to the special status of the municipality of Bamenda. It is unique and intended to achieve a compromise between the authority of the chieftains in whose territory the town was built and the dictates of the municipal administration (Bamenda II Council) made up of Mankon, Mbatu, Chomba and Nsongwa villages following Decree 74.23 of December 5th 1974, which organizes the municipalities but were not applied until 1977.

Evolution of the Central Town

The Bamenda Central market and Commercial center were initially at the Ntambag Plateau(Old Town). The influx of Nationals and non- nationals (Hausa/Fulani and the Ibo traders)into the town, brought about relocation decision to the present central market and commercial avenue. Hence the reason why the central business district distinguishes itself from its initial location, given rise to high rise buildings use for commercial administrative and residential. The contrast is very imminent in the peripheral areas of the CBD where high density per hectare, is common and buildings are constructed using permanent, non-permanent or semi-permanent materials.

Increased urbanization is a driving force which pushed the authority's to elaborate development plans-the Bamenda Master Plan in 1985, then followed by that of2011 and then the Bamenda II Council Land Use Plan of 2014. A number of sectorial plans were developed at different scales during the studies. Bamenda is witnessing the development of trade, transport and storage facilities. In carefully analyzing the initial concepts of previous urban planning documents before 1985, they were not plans developed except layouts for the benefit of local businessman, but also as transit points and branches of the large firms. Growth and development of socio-economic activities which to an extent were dominated by forces in and outside the region had made the centre of Bamenda, somewhat chaotic. This resulted to the creation of distinct functional poles of activities on the edges of the town like (Muwastu, Ntarinkon, Nitob and Ntatru). The branches of these national trading houses, warehouses and maintenance facilities are potential clients for the creation of light and heavy industries in these areas as cited in the Bamenda II land use Plan of 2014.

Population distribution

According to the 2005 census, the population of Bamenda II Council was 201,764 inhabitants. With an average annual growth rate of 2.54% from 2005 and 2019, the population of Bamenda II Council by 2019 is projected to be 261,285. It is important to note that new quarters have been created; firstly, by splitting some of the old ones and secondly, the creation of new settlements at the peripheries of the town due to urban expansion. The population figures of the new quarters are either incorporated into the old ones or the figures do not exist. The Mankon Fondom took up the initiative for all its Quarter Council to carry out a census. Its results are still awaited. Table 3.2 shows the population evolution from1976 to 2019.

Table 0.2: Evolution of the population of Bamenda II

RGPH	Population	Growth rate (%)
1976	48,111	-
1987	110,142	7.8
2005	201,764	4.9
2019	261,285	2.5

Source: 3rd GPHC BUCREP 2005, projected by Bamenda II Council in 2019

0.5 Limitations of the Study

The research was purposively carried out in Bamenda II Sub-division as it is part of a known food basket that feeds the larger population of Bamenda town. The focus was on smallholder farmers in Bamenda II and the impacts of climate variability on maize production. It also focused on two climatic elements namely; rainfall and temperature. The findings, however, will be generalized to other areas of the country that have similar climatic characteristics. The study focused on maize crop production excluding other food crops grown in the area. The study focused on only two climatic elements namely; rainfall and temperature while excluding the others, since these elements fall under the four main requirements for plant growth to occur which include; water, warmth, light and air. Secondly due to data limitations, the study focused on rainfall and temperature and their impact on maize production.

0.6 Significance of the Study

This topic was chosen as one of the contemporary issues affecting humanity in developing countries. Climate variability has negative consequences on crop production, especially those that are dependable on rain-fed agriculture, as the case of maize farmers in Bamenda II. Maize is both a staple and cash crop and its available has implications for food security.

Bamenda II is among the bread baskets of Mezam Division, which forms an important pillar in ensuring that maize yields are maintained at optimum. The challenges of climate variability are being felt by the small holder farmers of Bamenda II. According to the Cameroon Economic Review of Agriculture Report (2015) the level of maize yields has decreased over the last few years in Bamenda II. The research study will avail useful information to the farmers, researchers, policy makers, and stakeholders. To the farmers, the study will provide useful information regarding climate variation challenges on maize production and food security. This may help them to evaluate the effectiveness of their adaptation strategies towards climate variability. To the policy makers and stake holders like Ministry of Agriculture and rural Development (MINADER), Cameroon Agricultural and Livestock Research Organization, National Climate Change Response Strategy (NCCRS) and Ministry of Environment, Nature Protection and Sustainable Development (MINEPDED), the research findings will help them towards policy formulations that focus on climate variability and sustainable management of agricultural resources.

0.7 Statement of the Research Problem

Climate variability is neither rhetorical nor delusional. It is an unfortunate reality impacting many parts of the world today. Increasing temperatures and variations in rainfall for instance have been reported in many parts of the globe. Climate variation is a global concern but especially in developing world. Cameroon is among developing countries that have experienced the impacts of climate variability on agricultural productivity. Bamenda II Sub-division is characterized by variations in seasonal precipitation and temperatures.

The production of the country's staple food, maize was on a long-term decline, dropping by 70% over a period of five years in most areas. This was due to non- cultivation of the arable lands due to delayed rainfall and the high risk of making loss from agriculture as well as shortage of seeds for alternative crops among other. Bamenda II has suffered below average and declining cereal production as a result of erratic rainfall patterns, which are exacerbating the impact of rising unemployment and increased poverty. The purpose of this study is to analyze the impacts of climate variation challenge on maize production and food security in Bamenda II Sub-division.

The climate of Bamenda II is influenced by the nature of the undulating topography and urbanization. The changes that have been observed and experienced include: high average temperature, heavy rainfall lasting for a short period and prolonged dry season. These changes have translated into extreme weather events such as prolonged meteorological and agricultural drought, severe periodic floods and landslides region wide. Agriculture is one of the most vulnerable and exposed sectors to the potential adverse impacts of climate change.

Despite tremendous progress and improvement towards Government programmes and sector strategies aims at improving agriculture and environment sector, still vulnerability among farmers remains a challenge as it is linked to food insecurity and poverty. Climate variations is well recognized to be one of the anxieties (problems) for rural farmers as their available ability to coping with the prolonged drought period, floods and other extreme weather events is limited. The farmers of Bamenda II have been counting loses as maize yield levels have been declining and many attribute this failure partly due to climate variability among other factors. Usually, to adapt to climate variation requires cost, and the moment farmers adapt to, the economic costs of climate variation challenges reduced to some extent. The adaptive capacity of the vast majority of farmers in Bamenda II is limited due to financial and sometimes technical constraints. It is thus, very crucial to assess the challenges of climate variability on maize yield grown mainly for consumption. The proposed research study, therefore, sought to analyze the challenges of climate variability on maize and food security with the aim of helping the farmers to improve on existing climate variability adaptation strategies.

0.8 Research Questions

0.8.1 Principal Research Question

What are the impacts of climate variability on maize production and urban food security in Bamenda II Sub-division?

0.8.2Specific Research Questions

1. What are the characteristics and trend of climate variability in Bamenda II Sub-division?

2. In what ways has climate variability influenced maize production and food security in Bamenda II Sub-division?
3. What are the adaptation strategies implemented to curb the effects of climate variability and urban food insecurity in Bamenda II Sub-division?

0.9Research Objectives

0.9.1 Principal Research Objective

Examine climate variability impacts on maize cultivation and urban food security in Bamenda II Sub-division.

0.9.2Specific Research Objectives

1. Appraise the characteristics and trend of climate variability in Bamenda II Sub-division.

2. Examine the impacts of climate variability on maize production and food security in Bamenda II Sub-division.
3. Evaluate the existing climate variability adaptation strategies practiced by farmers to fight against food insecurity in Bamenda II Sub-division.

0.10 Research Hypotheses

1. Unusual and unsystematic climatic occurrences have led to significant variability in rainfall and temperature trends in Bamenda II Sub-division.

2. Variation in rainfall and temperature does not significantly affect maize production in Bamenda II Sub-division.
3. Adaptation measures implemented by farmers in Bamenda II Sub-division have significantly reduced maize farmer's vulnerability to climate variability and increase food production.

0.11Literature Review

This entails an overview of the previous studies related to climate variability and food security highlighting the knowledge gaps that the research study intends to fill. The sub-sections highlight on climate variability, its effects and adaptation strategies adopted by farmers in regions similar to the study area. A conceptual frame work is also used in showing the interrelationships between independent, dependent and intervening variables of the study.

0.11.1Climate Variability

In recent years, various climate change and adaptation related research studies have stressed out on the frequency and magnitude of climate extremes due to climate variability (FAO, 2009). This research will contribute towards filling the knowledge gap that exists on the effects of climate variability on maize yield with the aim of ensuring Bamenda II Sub-division is food secure.

The IPCC report, (2007) projected an increase in the global surface temperatures towards the end of the 21st Century of between 1.1°C and 6.4°C. The increase in the global surface temperatures is expected to cause a change in the climate-related parameters such as sea level, soil moisture and precipitation. It is projected that there will be variations in the intensity, predictability and frequency of precipitation (IPCC, 2007). A change in precipitation ultimately affects soil moisture and consequently vegetation. As a result of Africa's warming of 0.7°C within the 20th century period, various general circulation models have projected warming across Africa ranging from 0.2°C to 0.5°C per decade. East African region is set to experience a rainfall increase of 5% to 20% from December to February and a decrease in rainfall of 10% to 5% from June to August by 2050 (Hulme et al., 2001).

The IPCC (2007) suggested that with today's changing climate the result would be an increase in climate variability. Although extreme climatic events have been changing continuously over the years, an increased concern has been put forth about the increase in the degree of climate variability and extreme weather events because of anthropogenic factors (Malla, 2008). Rural households in Africa have been adapting to climate variability stress factors like droughts, which have been in existence for decades (Mertz et al., 2011). The most volatile climatic regions and communities are those highly exposed to the effects of climate variability and least able to adapt to these impacts (Luers and Moser, 2006). IPCC has made numerous documentations on global temperature and rainfall trends; however, the know-how on climatic changes and extreme events in climate is sparse when it comes to Africa (Herrero et al., 2010). Hence, this study assessed and gave a regional data on variability of rainfall and temperature for the period 1985 to 2015, with a focus on Bahati Sub-County, Kenya. The 30 years span of climatic data was a representative of the most recent average climate in the study region and sufficient duration to encompass a range of significant weather anomalies that have occurred in Bahati Sub-County, Nakuru County.

The East African region is highly vulnerable to climate variability effects such a shift in the growing season due to a high dependency by farmers on rain-fed agriculture and this has led to a decline in agricultural production (IPCC, 2007). Any variation in climatic variables negatively affects stability and supply in agricultural production (Gregory et al., 2008). In the least developing countries climate variability impacts are more notable and there are many reasons which elevate the vulnerabilities posed by climate variability such as; low level of technology, limited funds to combat effects of climate variability and a high dependence on rain-fed agriculture (Nath and Behera, 2011).

Various studies carried out in different altitude areas in the world revealed that temperature rise as an outcome of global warming may lead to increased crop yields in mountainous regions (Weart, 2010). Studies carried out in high-altitude regions such as northeast China and the UK revealed that rise in temperature has benefited agricultural production (Gregory et al., 2008). This means that climate variability could eventually be of benefit for mountainous agriculture as long as the limiting factor is not moisture.

There is no doubt that the earth is warming. Globally, surface temperature change is estimated to be 0.78°C since the 19th century with intervals of 0.72 to 0.85°C (Stocker et al., 2013). Precipitation on the other hand reported a small global annual mean with uncertain rising trend over the 20th century of about 1.1mm per decade (UNFCCC, 2007).Regions around mid to high level latitudes are said to experience more intense rainfall. These changes have received reasonable attention in the past years due to increased extreme events such as droughts, floods and hurricanes (Asadieh and Krakauer, 2015). According to IPCC (2007) it’s never been this warm for the past 1000 years and precipitation events are anticipated to become significantly intense under warming.

African’s climate is controlled by the interplay of both maritime and terrestrial activities that give diverse climate ranges in different regions (Boko et al., 2007; Mburu et al., 2015). In general, African continent temperatures are anticipated to increase by two to six degrees

Celsius by 2100 (IFPRI, 2010). In the Sub-Saharan African region, warming is also predicted to extend till the end of the century with temperatures hitting 5^{o}C by 2100 which is beyond the 1951 to 1980 baseline (Gebremedhin, 2018). In this case inland sub-tropics are said to warm the most (Serdeczny et al., 2016). These changes may seem homogenous, but they are not always. For example, the African tropical forests warming rate is 0.29°C, in South Africa a rate of 0.1 to 0.3°C has been noted (Sianungu, 2015).Eastern Africa has recorded declining trend in temperatures in areas nearing the coast and main inland lakes, they are also likely to increase more in the drier sub-tropical regions (Boko et al., 2007).

Multi-decadal variability is also significant. For instance, Herrero et al.,(2010) reports a likely increase in annual mean rainfall in East Africa which appears to be a relatively more stable albeit some evidence of long-term wetting and a decrease in both Mediterranean Africa and in the Northern Sahara regions. West Africa has also recorded a decrease in annual rainfall since 1960 by 20 to 40% (1PCC, 2007). Ziervogel et al.,(2006) further reports that winter rains will reduce by 40% in the Southern Africa region with higher rainfall anomalies and more intense and widespread droughts reported.

In Kenya, climate ranges from a humid tropical climate along the coast to arid areas inlands while temperatures shift with change in altitude. The Government of Kenya (GoK) (2009) reports that temperatures in the country have increased by 1°C over the past 50 years and warming is set to escalate by almost 3°C by 2050 (IPCC, 2007). Temperature increase is normally higher in the months March, April and May which has attributed to experiencing hot days and nights around this time. The northern parts of Kenya experience high temperatures of up to 35°C and the western and central parts of the country experience the lowest of 10°C and below (Naanyu, 2013).

Rainfall variability experiences regional rainfall differences. Long rains are less variable so inter-annual variability is as a result of short rains (Herrero et al., 2010). Rains are predicted to increase in some parts for instance around Lake Victoria region to the central highlands, east of the Rift Valley whereas the eastern and northern arid and semi-arid lands (ASAL) are anticipated to experience decrease in rainfall amounts (IPCC, 2007).

0.11.2 Food Security

Food security is referred to as a state when: “all people at all times, have both physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life,” Food and Agricultural Organization (FAO, 2016). On the other hand, food insecurity is a state when food is not easily accessible to households and they are facing difficulties in securing sufficient and nutritious food (Wakibi et al., 2015). Food insecure households are those that do not have both economic and physical access to food and this may be due to inadequate food, low purchasing power and poor usage of food at household level (Icheria, 2015). The four components of food security are stipulated as: availability, access, utilization and stability.

0.11.2.1 Food Availability

Food availability plays a very important part in food security. It refers to the production, distribution, and exchange of food in appropriate quality for people to meet basic food needs and this can be supplied through household’s own production or import (FAO, 2015). Food availability at household level can be described as the food’s physical existence, either from markets or own production including food imports and aid (Bunyasi, 2012). In evaluating food availability factors such as sufficiency supply of energy, animal proteins and the numerical quantity of food production are considered (Oyiga et al., 2011).

Food supply per person in developing nations in the last two decades has grown faster than the population and quality of diet has improved (FAO, World Food Program WFP and IFAD, 2013). For example, vegetables and fruits availability per person increased by 90 %, livestock products by 70 % and vegetable oils increased by 32 % since 1990–92 (FAO, 2015). This has changed into better diets, inclusive of increased protein of 20 % per person (Chauvin, 2012).Food availability in the SSA region has increased by nearly 12 % since (1990-92 and 2012-14) (FAO, 2010). In this period, countries such as Ethiopia experienced increase in food availability of 41 %, Mozambique 41 %, Cameroon 27 %, Sao Tome 23 % and Malawi 26 % (FAO et al.,2013).

0.11.2.2 Climate Implication on Food Availability

The most notable effects of climate variability on food availability is through changes in production. Extreme weather events disrupt production cycles (Sianungu, 2015). Climate changes affect crop production directly through environmental changes and indirectly by affecting distribution of incomes and growth (Zewdie, 2014). Warming of over 3°C will have negative effects on crop production. However, moderate warming of 1°C is anticipated to boost food crop and pasture growth in temperate regions, while it is likely to have negative effects in tropical and semi-arid regions, to cereal crops (Baldos and Hertel, 2014).

0.11.2.3 Food Accessibility

Physical availability of food alone is not enough to a household or a person to have access to food. Food accessibility is referred to as a household's capacity to access food of the needed quantity, quality, and nutritional type through production, purchase, gifts, borrowing or aid. Food access is directly associated with a household's financial ability to afford needed food for an active and healthy life (FAO et al., 2015). The ability to acquire food is influenced by physical and financial resources (allocation, preferences and affordability) (Zewdie, 2014). There may be adequate food in the market but due to the economic access aspect, some households may not be able to access it (Belloumi, 2014).

Food access is influenced by physical access which is determined by infrastructure and economic access. This is further determined by level of income, the cost of food and social access (Kabunga et al., 2014). Therefore, insufficient access to food could be due to high market prices or lack of capacity to acquire food and socio-political access for example traditional rights to common resources (USAID, 2013).Access to food is often measured using entitlement proxies such as price, income, monitoring, consumption or assets. It reflects the demand, uneven food distribution side of food security as well as cultural values within a community. It accentuates challenges in response to severe shocks such as unemployment, hiked prices or loss of assets resource base (Poppy et al., 2014).

In the Sub-Saharan Africa (SSA) nations, households are unable to access food for many reasons such as hiked food prices, markets inaccessibility, high poverty levels, employment status, level of education and rights to property. This will affect SSA communities that depend mainly on subsistence agriculture and markets as an important source of secondary food (Huppe et al., 2013; Zewdie, 2014).The effort to quantify food access is new and comes with a lot of challenges since households or individuals have many ways to react/respond to shock. Some of the indicators that have been put into consideration include; affordability or ability of consumers to buy food, money spent on food, market access, although a nearby market with plenty of food does not necessarily imply that households in the neighborhood are food secure (FAO et al.,2014).

0.11.2.4 Implication of Climate Variability on Food Accessibility

Climate variability is expected to place a strain on infrastructure. After production, food needs to be transported to the consumption point. Inefficient transport structures (absence or bad farm-to-market roads) delay the delivery and increase food prices (Choufani et al., 2017). Increased exposure to weather extremes such as heavy floods and long droughts is said to reduce household’s entitlement and hinder their food access. Entitlements in regard to households’ access to food rely upon food allocation, affordability, and availability USAID (2013). Climate variability as well hinders food access through its effects on production. Limited production means scarcity in the market hence high prices (Porter et al., 2014).

0.11.2.5Food Utilization

This is the ability or capacity of the household to utilize essential food nutrients from the food they consume or access (FAO, 2008). Utilization includes the nutrient content of the diet that is, how well food is utilized and whether the diet is well balanced with adequate nutrients (Chauvin, 2012). A house that has both physical and economic food access may be branded food insecure if it is not able to achieve a nutritious and balanced diet. These factors are influenced by preparation of food, knowledge on nutrition, access to clean drinking water and health care. These are particularly less if not lacking in most SSA nations where malnutrition is widely spread (Oyiga et al., 2011).

Utilization shows whether individuals and households use well the food that they have access to, whether they consume well balanced and nutritious foods they can easily afford or choose a nutritionally low diet. As well as if the foods they consume are safe and well-cooked so as to give their full nutritional value and substantive nutrients. Utilization is basically keen on dietary quality, especially intake of important minerals and vitamins (Poppy et al., 2014).

Food utilization is reflected when there is adequate food intake and members of the household are in good health care to reach a state of nutritional well-being where all physiological needs are met. Food wasting can lead to inadequate food intake and this can cause repeated occurrence of illnesses or infections. This will further cause acute under nutrition (Li and +Zheng, 2016). The number of undernourished and underweight children under five years has decreased in all developing regions since the year 1990, thus improved nutrition resulting from easy access to and availability of food (FAO et al., 2013).

0.11.2.6 Implication of Climate Variability on Food Utilization

Changes in climate affect the rate of production of different food types and this may hinder the dietary requirement of a household. Climate variability as well can affect the income levels and the ability of households/individuals to attain the required foods to meet a nutritious and well-balanced diet (Belloumi, 2014).

0.11.2.7Food Stability

It is determined by the availability and access to food. Stability supports availability, access and utilization as well as captures the level of uncertainty or susceptibility to future commotions in food security. For instance, food chains, processing, storage, marketing and distribution constitutes the integral, methods that have preserved the food system from instability (Bunyasi, 2012). Risks to stability include climatic conditions, conflict, price shocks, production and supply, swing in food and input prices and disease, among other factors (FAO et al., 2013).

0.11.2.8 Climate Implication on Food Stability

Increased extreme weather events will destabilize the local food system hence increased cases of food emergencies. Unpredictable weather can lead to unstable harvests hence instability of food production (FAO, 2008). The climatic variability produced by more frequent and intense weather events can upset the stability of individuals' and government food security strategies, creating fluctuations in food availability, access and utilization Weldearegay and Tedla (2018).

0.12Climate Variability and Food Security

Climate variability poses a serious threat to food security globally. It damages the resource base on which agriculture depends on and seriously affects crop production (Belloumi, 2014). Increased scientific evidence suggests that climate changes are set to magnify climatic variation, with significant changes in weather behavior, particularly seasonal changes and year to year's variability (GoK, 2007). Climate variability may be affected by changes in climate related abiotic and biotic stresses and also changes in accumulation of atmospheric carbon dioxide, deposition of acid and the ground level ozone (Oyinbo et al., 2012). Food production will become more unpredictable globally and this calls for advanced understanding of the causes and effects, and dispersion of appropriate responses in regard to regional scale (Manyeruke et al., 2013). Yield changes and all other factors held constant, would reduce food consumption and production thus deteriorating food security conditions (Adane et al., 2015).

In regard to food systems, rainfall and temperatures are the most essential to measure (Comoe', 2013). The difference between highs and lows of rainfall and temperature extremes occurs and the intensity of the incidences varies (Ziervogel et al., 2006). It's anticipated that low latitude countries mainly in the tropical and sub-tropical regions would mostly be at risk to decline crop productions. This will result in some areas in the tropical regions becoming undesirable for agriculture (Oyiga et al., 2011).

Rainfall fluctuation, together with extremes, can have intense impacts on agricultural production. The intensity of rain storms could increase, and precipitation could become more variable. Rainfall variability can affect both the intensity of soil erosion and soil moisture content which are crucial to crop yields (Oyiga et al., 2011). Growing seasons are more sensitive to supply of water. According to Thornton et al., (2012), seasonal rains shortening decreases crop production, especially if the supply of water is insufficient towards the end of a growth-cycle when water demand is higher. This comes as a result of high temperatures gradient in high altitude. Water deficit/scarcity could lead to water limiting and raise the cost of water as well as reduce opportunities to expand agricultural lands by irrigation (Oyiga et al., 2011).

Africa is among the regions susceptible to climate variability (UNFCCC/IPCC, 2007) because it is already hot and dry, and the economy purely depends on rain-fed agriculture (FAO, 2010). Due to warming and drying, by 2050, total production in the African continent will decline by a percentage of 10–20 (Thornton et al., 2012). Anticipated decrease in yield in some countries could be up to 50 % by the year 2020, and overall crop produce could come down by a percentage of 90 by 2100, with smallholder farmers being the most affected (Barrett, 2014). SSA depends on rain-fed agriculture and changes in rainfall pattern would reduce crop yields and agricultural produce is projected to decrease from 9-21 % by 2080 (Belloumi, 2014) a rise in temperature and changes in rainfall are likely to reduce the production of stable foods by up to 50% as well (Zhao et al., 2017).

Climate variability may also bring with them new weeds, pests and diseases. Temperatures beyond optimum tolerated by crops will affect the biology of plants, leading to decrease in food production. The predicted losses in food crop add up to about 33 % by 2060 (Comoe', 2013). Prolonged droughts, unexpected changes in normal weather patterns in the past few years have jeopardized food security, particularly in vulnerable parts of Kenya (Naanyu, 2013) a consequence that has ledin the reduction of crop produce by 30 % (NEMA, 2007). The 2009 climate variability manifestation was seen in the general crop harvest failure (FAO, 2010). Kajiado County has also experienced a share of extreme events with great impacts on livelihoods.

0.12.1 Climate Variability Impacts on Food Production

Crop yields global analysis between the year 1981 and 2002, shows that rise in temperature has had negative effects in wheat, maize, and barley with a total cost of around $5 billion yearly (Fei et al., 2017). Maize and soybean yield in the U.S under the IPCC scenario were predicted to decline by 30 % to 46 % with the slowest warming trend (Araya et al., 2017). In Europe low crop yields were recorded in the year 2003 when a heat wave was experienced and temperatures ascended up by 6°C above average, and annual precipitation reduced by 50 % below average (Ainsworth and Ort, 2010). On the other hand, climate variability may increase production and set up new agricultural possibilities at high latitudes in areas of Canada and Russia, (Rosegrant et al., 2009).

Numerous reports have already revealed that a mix of increased rainfall changes and rise in temperatures will bring down production of stable crops (Alemaw and Simalenga, 2015). In 2010, cereal yields were 3563.538 kg/h globally and 1533.794 kg per hectare in Africa (Singh, 2018). A meta- analysis and a review by (Knox et al., 2012)found out that the mean change in yields of maize, sorghum and millet were expected to be 5 %, 15 % and 10 % respectively by 2050 in Africa. It is anticipated that cereal production will come down by 3.2 % by the year 2050 due to climate variability (Ali et al., 2017). Food prices is an important indicator of climate effects on food security; wheat, maize and rice prices in SSA are anticipated to increase by 15 %, 7 % and 4 % by 2050 respectively (Belloumi, 2014).
A recent analysis of over 20,000 historical maize trial yields of over eight-years revealed maize were cut down by 1 and 1.7 percent increase beyond 30°C under optimal and drought conditions respectively (Hellin et al., 2012). In some parts crop yields will decline for instance southern Sudan, northern parts of Uganda, and the semi-arid parts of Kenya and Tanzania while in some parts crops produce will rise for example southern Ethiopia highlands, western and central highlands of Kenya (Thornton et al., 2009).

Temperatures beyond optimum during the reproductive stages have far reaching effects beyond reducing the period of grain filling and photosynthesis. High-temperatures during the reproductive period may cause sterility (Teixeira et al., 2013), fertilization, and grain formation are affected, which is mostly associated with less yields (Ainsworth and Ort, 2010). Along with high temperatures, higher atmospheric CO_2, may harbor many pests and diseases that will affect agricultural produce (Ziska et al., 2011). Temperature harbors insect development, survival and distribution. Insect population increase with increase in temperature and this is likely to diversify. For instance, recent warming in Canada and the U.S. have led to increased insect species such as mountain beetle (Ben-Ari et al., 2016).

Hedhly et al., (2008) studies show that high temperatures alter genetic frequencies, speed up the rate of pollen tube growth, stigma and ovule development, thus preserving the male-female relationship required for a complete seed set. Nevertheless, under intense-temperatures, this relation can be lost, causing low fertility and lower yield. Loss of relationship can also have consequences for insect-pollinated crops, where changes in annual temperature can destroy insect life cycles with crop-flowering physiology (Memmott et al., 2007; Ainsworth and Ort, 2010). Ability to tolerate high temperatures depends upon the period and timing of heat levels together with the plant growth stage (Reynolds et al., 2010). Produce at low latitudes are speculated to reduce, with increase in temperature however global production is anticipated to go up (Easterling et al., 2007; Ray et al., 2015). Precisely, all major food grain yields are already going down (Fischer and Edmeades, 2010). Water on the other hand is very vital for plant development. Water scarcity during the reproductive period of food grain can be very destructive (Lobell and Gourdji, 2012), because it is required for evapo-transpiration and high physiological sensitivity when determining its main yield thus stress may mean low yields (Omoyo et al., 2015).

0.12.2 Climate Variability Impact on Maize Production

Climate Variability is envisioned to cut back maize yields by 3 to 10 % by 2050 globally (Rosegrant et al., 2009; Ben-Ari et al., 2016). Maize is grown from latitude of 50°N to 40°S, and altitude of 4000 m above sea level (Belfield and Brown, 2008). In Sub-Saharan Africa (SSA) maize was cropped on about 25 million hectares, which represented 27 % of total land under cereal and 34 % of cereal production in the year 2005-2008 (Smale et al., 2011; Adhikari et al., 2015). Low produce in this region is widely linked with prolonged droughts, low soil fertility, weeds, pests, diseases, low input and unsuitable seed varieties (Hellin et al., 2012).

Maize in Cameroon is a staple food and widely consumed food with an area under cultivation estimated at 1.6 million hectares (GoK, 2005). Within Cameroon, the possible average maize produce is a scrimpy 1.1 t/ha^{-1} (Omoyo et al., 2015). The optimum temperature for growing maize is reported to be 25°C. Temperatures beyond 30°C are said to reduce total maize yield by 1 % even under normal rain fed conditions (Fisher et al., 2015). Maize may grow with as low as 300 mm rainfall, but preferably 500 to 1200 mm for better results. Crop failure could occur if lower than 300 mm of rain were experienced depending also on soil type and stored soil moisture (Belfield and Brown, 2008). Thus, in low rainfall seasons (300mm) it appears that it is important for rainfall days to be spread out with rainfall events not concentrated for time periods nor should the daily rainfall events be strictly uniform (Duffy and Masere, 2015).

0.13 Adaptation and Mitigation strategies

Climate variability mitigation and adaptation go hand in hand and their impacts are simultaneous so taking on an integrated approach can be the best way forward. Mitigation measures represent good options to adaptations in the climate systems.

0.13.1 Adaptation Strategies

Adaptation is a response that improves an outcome or alleviates adverse impacts or an adjustment in natural systems to deal with the consequences (IPCC, 2007). It involves taking practical actions to manage risks from climate impacts, protect communities and strengthen the resilience of the economy. Adaptation should be area specific because different locations are confronted with different climatic conditions. People depending on agriculture as a source of livelihood have devised ways to cope with climate variability (Alemaw and Simalenga, 2015).

Mexico and Argentina have adopted proactive adaptation such as; change of planting dates and variety of crops, diversified cropping and grazing, diversification of sources of income by keeping livestock, issuance of insurance for crops and establishment of local fund pools (IPCC, 2007). In Asia the Philippines have laid down effective adaptation practices such as a change to drought tolerant crops, construction of shallow tube wells, irrigation during droughts, water dams/ reservoirs construction, use of fire lines and contained burning, soil, water conservation measures application for elevated farms, harvesting rainwater and hydroponic farming (Manyeruke et al., 2013).

Adaptation is already being practiced in African agricultural systems. Some countries like Sudan have used adaptation practices such as rainwater harvesting and traditional water conserving measures (IPCC, 2007). In Ghana, adaptation practices in farming include intensification of crops, and experimentation with hybrid varieties, harvesting of crops early, and forming cooperatives with farmers to help in labor division (Connolly-Boutin and Smit, 2015). Drought management in Ethiopia, flood management in Mozambique, climate insurance in Malawi, and agriculture in Mali. Ethiopia has also put in place policies and planning for drought management, in order to manage the iterating droughts (Mugi-Ngenga et al., 2016). In Kenya Lobell et al., (2011) suggests transitioning from maize to sorghum farming because of the ability of sorghum to tolerate water scarcity and high temperatures (Bilham, 2011).

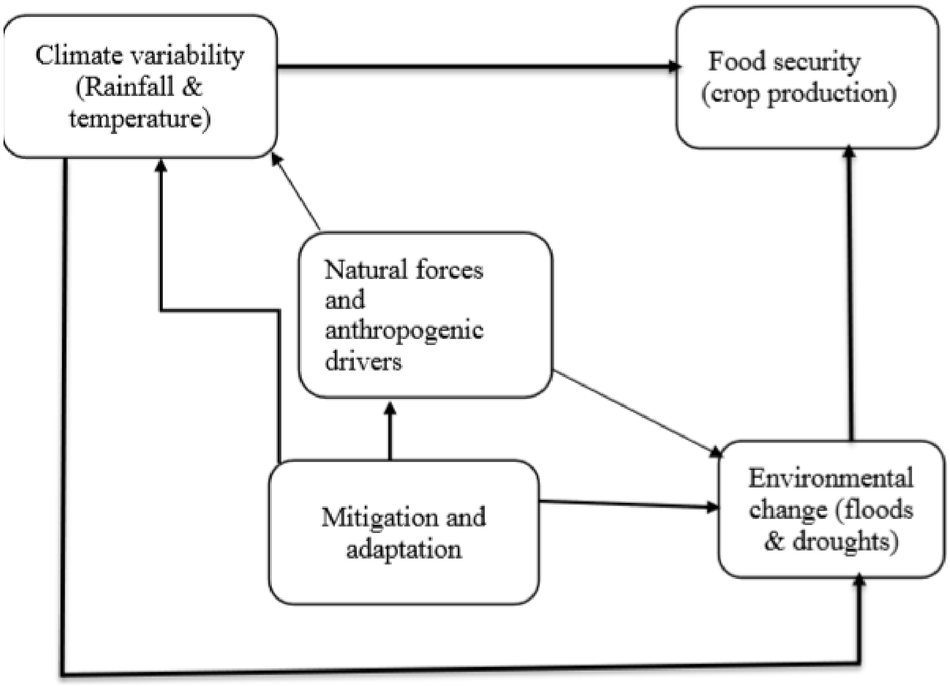
0.13 2Mitigation Strategies

Mitigation is the changing of current practices to reduce the effects of human activity on the climate. Mitigation calls for actions to minimize the concentration of greenhouse gases and sink carbon in the short term, and long-term development choices that will reduce emissions (IPCC, 2007). Mitigation for many countries continues to be resource.

0.14 Conceptual and Theoretical Frameworks of the Study

0.14.1Concept of Climate Variability and Food Security

The study aimed at examining climate variation challenges on maize cultivation and food security, establishing household food security status and evaluating effectiveness of coping strategies in the study area. The independent variable for the study was climate variability (rainfall and temperature). Food production and environmental change were dependent variables while natural and anthropogenic drivers, and mitigation and adaptation strategies were independent variables (Figure 0.2).



Source: FAO, 2008

Figure 0. 2.: Conceptual Framework for Climate Variability and Food Security

Climate variability has far-reaching effects on food grain production and thus food security. Food production will be affected by shortening of growing seasons, shift in planting seasons, increased crop pests and diseases, loss of soil fertility and decreasing moisture content. This can lead to seasonal crop failure and long-term production problem leading to low yields hence food insecurity. Climate variability as well can affect food access in a way that, as agricultural produce decreases, food prices shoot, and the purchasing power reduces. Natural and human (anthropogenic) drivers such as will accelerate climate variability (rainfall and temperature) by changing weather patterns making production more unpredictable.

Environmental change in this case involves the extreme weather events such as droughts and floods. More intense and increased frequent extreme weather events and increasing abnormalities in seasonal rainfall changes are already having significant impacts on crop yields and thus food insecurity. Erratic and unpredictable rainfall will lead to changes in rainfall thus floods; high temperatures coupled with low rainfall can lead to droughts. Both natural and human drivers will accelerate the extreme events thus reducing food production. Appropriate climate adaptation and mitigation strategies will minimize the effects of natural and human drivers hence stabilizing the effect of climate variability on the environment and increase food production hence food security.

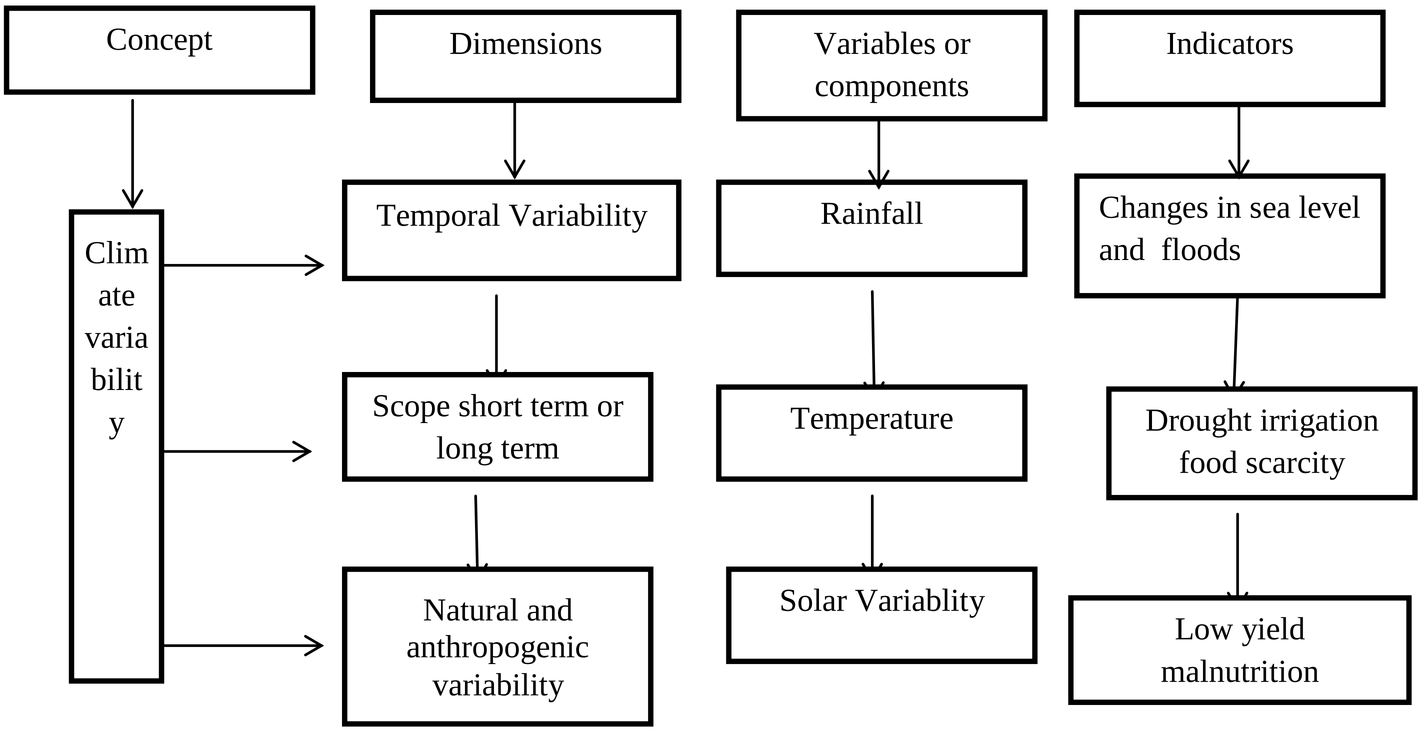
0.14.2The Concept of Climate Change

In general, climate change is a modification of climate parameters or elements within a course of time usually 30 years and above. Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period. According to IPCC, TAR 2001, climate change may be due to external forcing or natural processes, or to persistent anthropogenic changes in the composition of the atmosphere or land use. Article 1 of the UNFCCC defines climate change as “a change of climate which is attributed directly or indirectly to human activities that alter the composition of the global atmosphere and which are in addition to natural climate variability observed over comparative time period”. The UNFCCC makes a distinction between climate change attributable to human activities altering atmospheric composition and climate variability attributable to natural causes.

0.14.3 The Concept of Climate Variability

According to the Inter-Governmental Panel on Climate Change (2013) cited in Niba and Bailack (2022), climate variability refers to variations in the mean state of climate on all temporal and spatial scales beyond that of individual weather events. This variability may be due to natural processes within the climate system (internal variability), or due to anthropogenic forcing (external variability). Climate variability is a socio-ecological system which cannot be understood and evaluated by relying on physical sciences alone because its effects trickle down to the lowest level of society, particularly in rural communities (Tume and Tanyanyiwa, 2018). This stems from the fact that rural communities rely on climate-sensitive sectors that include agriculture and other primary activities for their livelihoods. Climate change has exacerbated food-supply issues by impacting crop production, food security and availability and crop distribution. With the shifting precipitation patterns and the rise of land and ocean surface temperatures by 0.65 to 1.06°C between 1880 and 2012 (IPCC, 2013), there has been a decrease in crop yields forcing many developing countries to become increasingly dependent on food imports. With the shifting precipitation patterns and decreased crop yields that are expected with climate change, many developing countries will become increasingly vulnerable to short and long term effects. At the same time, pressure to cultivate marginal lands or use unsustainable cultivation practices may lead to increased land degradation (Biernmann et al., 2016). Food and resource scarcity is particularly problematic in the developing world, which is heavily reliant upon local resources for day-to-day survival. Climate change could further jeopardize food crops production and security as precipitation patterns are shifted and temperatures increase. On its own, climate change is projected to increase the number of malnourished between 40 and 170 million globally. Even slight increases in temperature are anticipated to reduce crop yields, particularly in tropical latitudes, including Sub-Saharan Africa (SSA) (Hasan et al., 2017). Climate variability indicators manifested in the relationship between temperature and rainfall provides ideal conditions for the development of crops in rain-fed agricultural systems. Rain-fed croplands account for more than 80% of global crop area and 60% of global food output, but are especially susceptible to the impacts of climate change. Salient cropland management for vegetable production in the phase of rainfall variability cartels integrated knowledge-based approaches that embrace locally adaptable practices in optimizing the productive proficiencies of market gardening lands in urban and per-urban areas. Climate variability is one of the most significant determinants of year to year crop production variations both in high-yield and high technology agricultural areas. With the shifting precipitation patterns and the rise of land and ocean surface temperatures by 0.65 to 1.06°C between 1880 and 2012, there has been a decrease in crop yields. This is more patent in Africa where agriculture contributes about 70% of the GDP. By 2022, climate variability is predictable to reduce crop yields from rain-fed agriculture by up to 50% in Africa (Obwocha, et al., 2022).Climate variability explains the state of the climate that can be identified (for example by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer (IPCC, 2014). Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use. The United Nations Framework Convention on Climate Change (2015), in its Article 1, defined climate variability as: “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods.” The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. Hence today, climate change usually refers to changes in modern climate which is sometimes qualified as anthropogenic or human induced climate change or "Global Warming" (Biermann, 2007).

According to Glosbe (English Dictionary), rainfall variability is the semi-arid conditions affecting large areas, seasonal droughts, very high rainfall variability and sudden high intensity rainfall. Rainfall variability can be distinguish in two types namely; spatial and temporal variability. Spatial variability refers to the variation of rainfall amounts across a region for a specific time interval. This type of variability takes into consideration, a large or broad surface area. Temporal variability is the variation of rainfall amounts at a given location across a time interval. This is the variability considered at a specific location. This is thus the variability on which the study focuses.



Source. Author's Conception

Figure 0. 3: Conceptual framework for climate variability

0.14.4 The Concept of Production

Production refers to the creation of goods and services to satisfy human wants. These goods or services depend on natural resources (land), human skills efforts (labor), equipment and materials (capital) and organization (management). Productivity is a good indicator of land conditions since it directly reflects changes in the quality of the land. It happens that a good condition for production is that which allows crop growth, seed germination, and emergence of young plants, root growth, plant development, grain formation and good harvest. This study look at production as the availability of land for the cultivation of maize, the ability of the farmer to cultivate with the available resources put in place and subsequent good harvest to meet home challenges and that of the community in which they belong.

0.14.5 The Concept of Impact

Impact is the action of one object coming forcibly into contact with another object. The Oxford English Dictionary defines impact as having a strong effect on a situation or someone. This definition is further supported by Merriam-Webster.com, defining impact as having a strong and often bad effect on something or someone. Impact can be positive or negative. Positive impact is the outcome of a phenomenon which leads to changes that improve a system. For instance, global warming has a positive impact on agriculture in the polar regions of the world. Conversely, the appellation denotes a situation of misery on a system. Within the context of this study, impacts are the effects of rainfall and temperature variability on maize production.

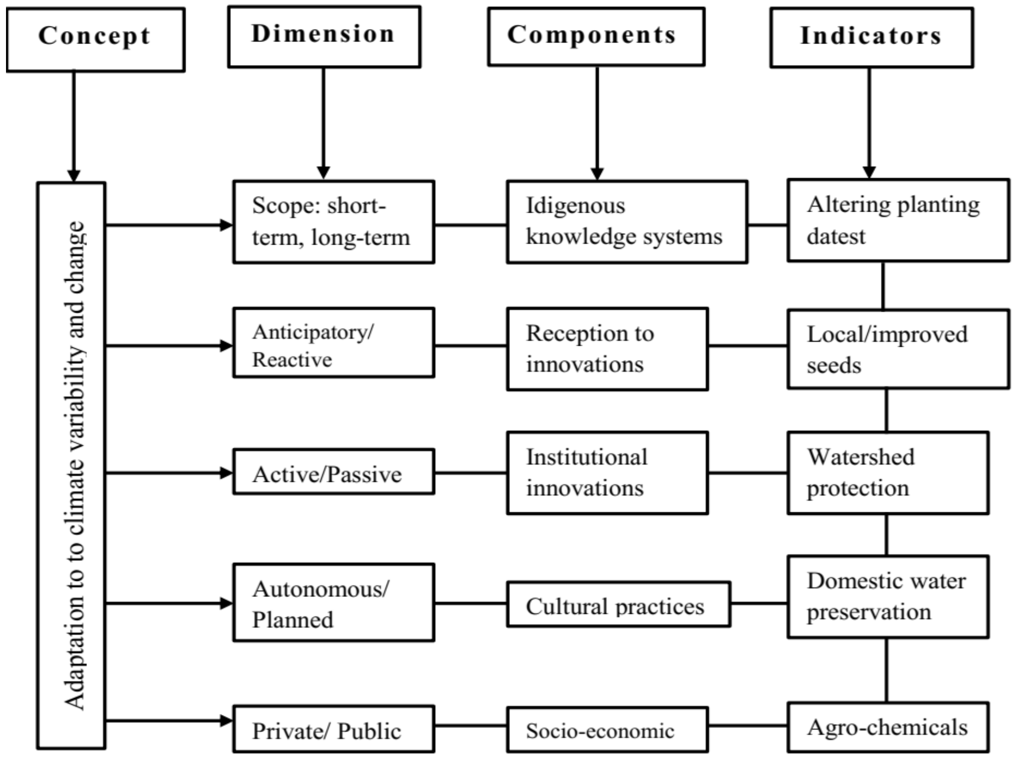
0.14.6 The Concept of Resilience

According to the Inter-governmental Panel on Climate Change (IPCC, 2007) resilience is the ability of a social or ecological system to absorb disturbance while retaining the same basic structure and ways of functioning. The capacity of self-organization and the capacity to adapt to stress and change. According to Holling (1973), resilience is a measure of the persistence of a system and their ability to absorb change and disturbance and still maintain the same relationship between population and state variables. In 2002, Gunderson and Holling extended the ecological definition to the magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behavior.

So, resilience in this study is the ability of maize crop to withstand the stress brought by rainfall and temperature variability.

0.14.7 The Concept of Adaptation

Adaptation to climate variability is a transitional phase of awareness to the construction of actual strategies and plans in societies (Figure 0.4).



Source: Author's conception, 2021

Figure 0. 4: Climate variability adaptation of the Bamenda II Sub-division

The concept of adaptation and planning was brought forth by Mimura and Polarity (2014) during the publication of the second volume of Impacts, Adaptation and Vulnerability of the Fifth Assessment Report (AR5-II) of the Intergovernmental Panel on Climate Change (IPCC) Climate Change 2013/2014 and was prepared by its working Group II. Combined efforts of a broad range research from international organizations, scientific reports, and media coverage have raised awareness on the importance of adaptation to climate variation and change, fostering growing number of adaptation responses in developed and developing countries. This represents major progress since the IPCC Fourth Assessment Report (Mimura et al., 2014). Literatures gotten from most research work illustrate heterogeneity in adaptation planning related to the context specific nature of adaptation. Each community has a way of adaptation depending on intensity and severity of the climatic hazards. Although attention to climate change impacts and disaster risk management are key elements of adaptation, they appear to have a more prominent role in the early stages of planning and implementation (Eakin, et al., 2012, IPCC, 2012).

The adaptive capacity of communities is determined by their socio-economic characteristics. Enhancement of adaptive capacity represents a practical means of coping with changes and uncertainties in climate, including variability and extremes (Taratola, 2008; Orindi, 2009). In this way, enhancement of adaptive capacity reduces vulnerabilities and promotes sustainable development (Abeysinghe, 2013; Wooda et al., 2014). This theorisation culminates in the Earth-Human Systems model that shows the interactions between climate change, impacts and vulnerabilities, adaptation and mitigation (socio-economic development) and drivers of the local and global climate system. Climate variability is likely to increase the frequency of meteorological and agricultural droughts in Bamenda. This are will increase the frequency of short hydrological droughts. Climate change negatively impacts freshwater ecosystems by changing stream flow and water quality.

Adaptation planning and implementation initiative illustrate differences in the role of national governments in the governance structure of countries, multi development agencies and organizations (Taratola, 2008). National governments often have a complementary role in adaptation planning that is reflective of the governance. They aim at creating awareness to the general population about climate variation adaptation at different dimension. With regards to climate adaptation strategies in the agricultural sectors, the national dimension first to define vulnerability and climate-related risks and hazards, increase technical and adaptive coping strategies. This is done through either media programs, round table conferences on climate variability impacts and adaptation strategies.

Indigenous adaptations strategies are embedded in climate change adaptation as an iterative risk management process (IPCC, 2014) and anatomy of adaptation to rainfall variation and change (Smit and Pilifosova, 2000; Blümel, 2009). It is the only way to cope with the impacts that are unavoidable in future (IPCC, 2007). It provides an impetus to adjust economic activity in vulnerable sectors and to support sustainable development, especially in developing countries. Adaptation is not an easy option and it can only reduce, not remove the impacts (Stern, 2007; Reid and Huq, 2007; Ali and Erenstein, 2017). It has multiple feedbacks (people and knowledge) shape the process and its outcomes. There are be some residual costs in climate change adaptation (impacts and the cost of adapting). Without early and strong mitigation, the costs of adaptation rise sharply.

Adaptation involves the adjustment to enhance the viability of social and economic activities to reduce their vulnerability to climate as well as its current variability and extreme events (Taratola, 2008). Adaptation is a set of adjustments within a field of practices, processes or structures of a system that is undergoing actual change (Smit and Pilifosova, 2001). Change sometimes can be spontaneous, planned and can be carried out in response to or in anticipation of change (Watson et al., 1996).

‘Adaptation to What’ can be various manifestations of stress (Philander, 2008). This cuts across crops adapting to annual average precipitation uncertainties, daily precipitation or experience hourly precipitation extremes, droughts, crop failures or income loss. Relevant climate characteristics which agriculture needs to adapt with are temperature, precipitation and moisture content (Taratola, 2008).

‘Who and What to Adapt’ is a system definition of the subject and boundaries. Subject and boundaries can be micro-ecological zones, farmers, crops and water resources. Farmers adapt to changing agricultural patterns, changing land uses or engaging in other activities which are income generating to help balance the income loss from agriculture (Philander, 2008). Ecologically, crops adapt by growing new species of tubers (as in the case of solanum potato). Also, new crop species can be introduced into the system through new hybrids which are be resilient to climate change (Dowinget al., 1996). It is important to note that vulnerability and adaptive capacity of crops will depend on the system characteristics to promote, exhibit and stimulate the occurrence of nature of adaptation.

‘How Adaptation Occurs’ depends on the adaptive response of the system to climate stimuli and it can take several forms. These are autonomous, spontaneous, passive or natural adaptation (Carter et al., 1994; Tripathi and Mishra, 2017). By autonomous response, crops with high sensitivity to climate stimuli like solanum potato tend to respond faster and highly vulnerable to this stimulus, thus, needs much time to adapt. Crops like maize which are favourably grown under warm conditions are not very sensitive to climate stimuli and as such, adapt spontaneously (Kolawoleet al., 2016).

'How good is the Adaptation' is based on the evaluation which depends on several criteria and principles of evaluation. This takes into consideration the use of conceptual models and numerical models (Smith et al., 2009). Conceptual models are based on the use of astronomic data from meteorological stations correlating with crop production over a variety of crop species. Numeric evaluation is based on comparing the productivity ratio of given improved species to the farmer.

Putting the right policy frameworks in place encourages and facilitates effective adaptation by households and communities. Poverty and development constraints will present obstacles to adaptation, but focused development policies can reduce these obstacles. Adaptation should be integrated into development policy and planning at every level. This will incur incremental adaptation costs relative to plans that ignore climate change. Ignoring climate change is not a viable option. Inaction will be far costlier than adaptation (Stern, 2007). Climate and environmental issues have dominated debates at local, national and international circles since the dawn of global active environmentalism in the 1970s. Climate plays an overriding role in the natural environmental system.

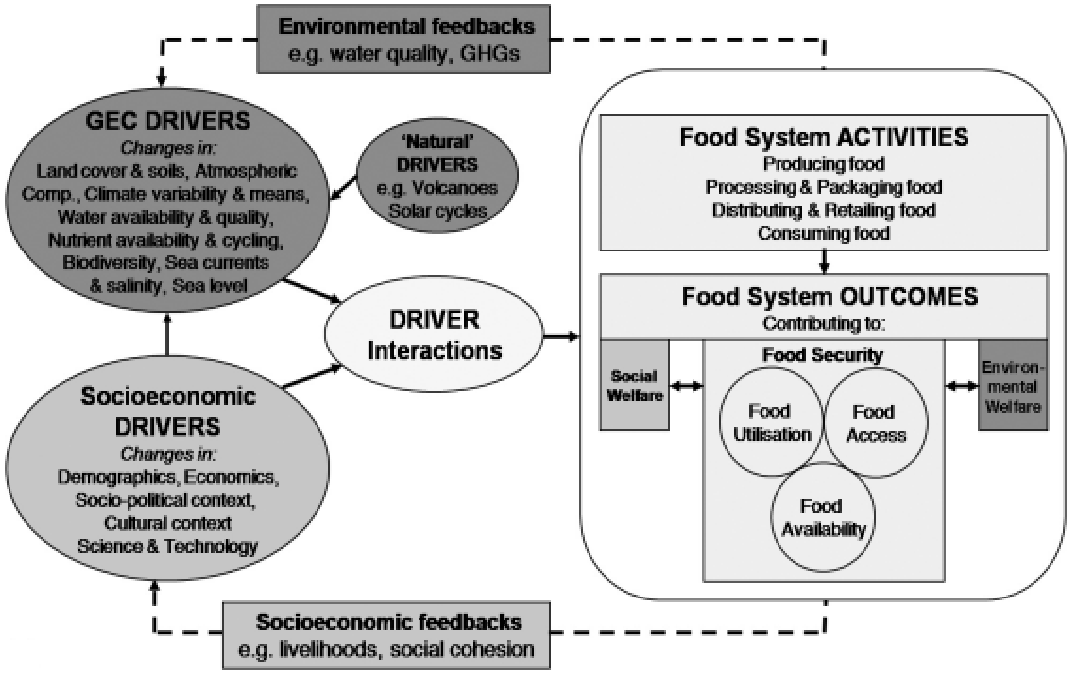
There is a significant increase in the number of planned adaptation responses at the local level inrural communities of developed and developing countries. Climate adaptation is context dependent and it is uniquely linked to location, making it predominantly a local government and community level of action. Local knowledge-based adaptation is focused primarily on the use of traditional knowledge to increase adaptive capacity at the community level, example in Upper Bui Basin traditional knowledge is highly applied in coping with variation in climatic factor like adapting to two seasons planting of different crop species that can withstand the condition of the season they include dry season planting of bean, cow pea, sweat potatoes from Mid-August. Villages in the lower agro-ecological zones of the area are highly noted for this while agro-ecological zone located in high altitudes are limited out of the double cultivation but specialized more in market gardening crops, rainy season bean sand double cultivation of Irish potato in the rainy periods. Individual and farmers groups need sufficient knowledge and implementation on the following adaptive strategies use drought early warning, harvest rain water, change tilling practice, use appropriate crop varieties, analyses of rainfall and temperature data to cope with changes in climatic factors determining crop production. It is noted some of the adaptive measures are carried out by indigenous farmers but more need to be done to enhance food sustainability in the locality.

Although Adaptation plans are being developed and document at the national, sub national, and community levels and by the private sector, however, there is still limited evidence of adaptation implementation. Implementation remains challenging because in the transition from planning to implementation the many interested parties must overcome resource, institutional, and capacity barriers. The difference in time scale between medium and long-term adaptation plans and pressing short-term issues poses a significant problem for prioritizing adaption.

0.14.8 The Concept of Food Security

Food has always been linked to environmental conditions with production, storage and distribution, and markets all sensitive to weather extremes and climate fluctuations. These are drivers of Global Environmental Change (GEC) and socio-economic drivers (Figure 0.5). These drivers interact to influence food system activities and food system outcome, with environmental and socio-economic feedbacks. Food production and quality are also sensitive to the quality of soils and water, the presence of pests and diseases, and other biophysical influences. Over millennia people have adjusted the production and consumption of food to the spatial and temporal variation in the natural environment, and the growing size and complexity of food systems have in turn transformed the landscapes that humans inhabit (Liverman and Kapadia, 2010).

The scope and scale of interaction are changing dramatically, particularly in relation to the risks of climate change, biodiversity loss and water scarcity; in terms of linkages to energy systems; and as food systems become more global in their networks of production, consumption and governance.

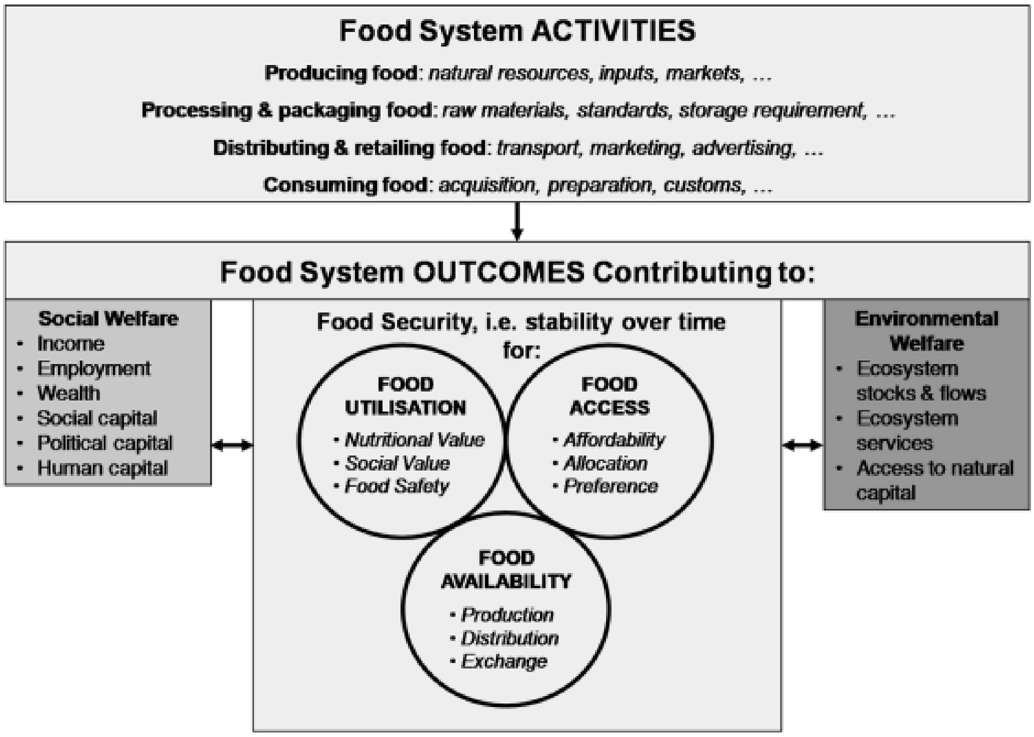


Source: Ericksen et al., 2010

Figure 0. 5: Food systems drivers and feedback

This has started to raise concerns about food security, not only in governments, but also for private sector and NGOs. Food security exists when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life (FAO, 1996). Food security is underpinned by food systems that link the food chain activities of producing, processing, distributing and consuming food to a range of social and environmental contexts. Within the food production system activities, natural resources, inputs and markets are vital (Figure 0.6). Processing and packing food also entail the use of raw materials, standards (quality) and storage requirements.

Distributing and retailing food is facilitated by transport, marketing and advertising. Finally, food security is guaranteed when people are able to consume the produced food through acquisition, preparation (cooking) according to customs and traditions. This is sustained through food utilization, food access and food availability (Ericksen et al., 2010). The food security situation of a given unit of analysis can be explained in terms of three components, each of which has a number of elements. Food availability is the amount, type and quality of food a unit has at its disposal to consume; food can be available through local production; availability can rely on distribution channels to get food where it needs to be; and availability depends upon mechanisms to exchange money, labor or other items of value for food.

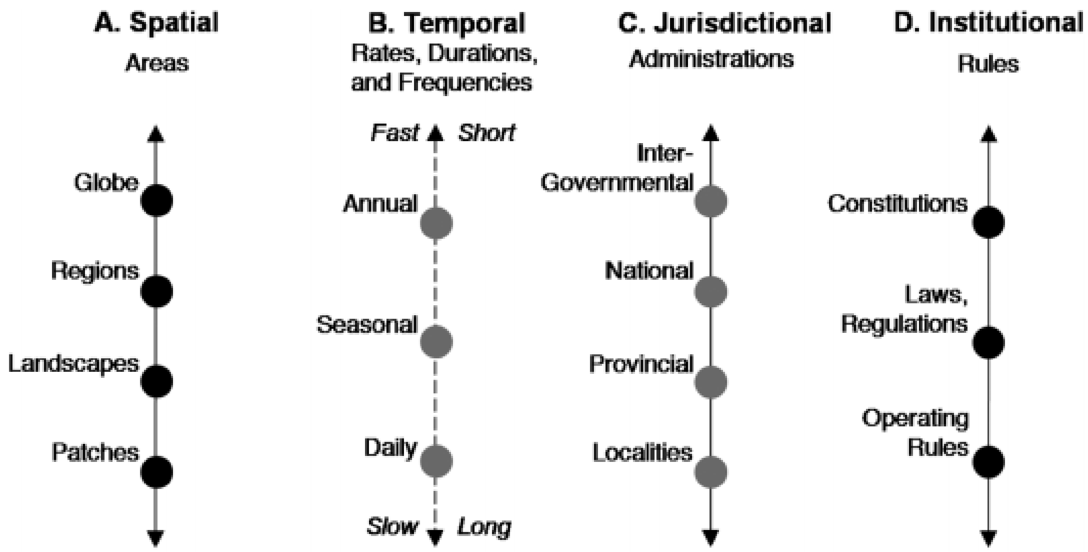


Source: Ericksen et al., 2010

Figure 0. 6: Components of food systems

Access to food is the ability to gain access to the type, quality and quantity of food required, and it can be analyzed in terms of the affordability of food that is available, how well allocation mechanisms such as markets and government policies work, and whether consumers can meet their social and other food preferences. Finally, the utilization of food refers to ability to consume and benefit from food; it thus depends upon the nutritional and social values of food, and the safety of available and affordable food.

A predominant feature of 21st Century food systems is that they are inherently cross-level and cross-scale. Scale can be spatial, temporal, quantitative or analytical dimensions used to measure and study any phenomenon, and 'levels' as the units of analysis that are located at different positions on a scale (Figure 0.7). GEC and food security issues span a number of different scales (spatial, temporal, jurisdictional, institutional, management) and a number of levels along each of these. Food systems are inherently multi-scale and multilevel (Ericksen et al., 2010). For example, household food security is influenced not only by factors operating at the local level; district, national and even international factors (grain prices) are also very influential.



Source: Ericksen et al., 2010

Figure 0. 7: Different scales and levels critical in understanding and responding to food system interactions

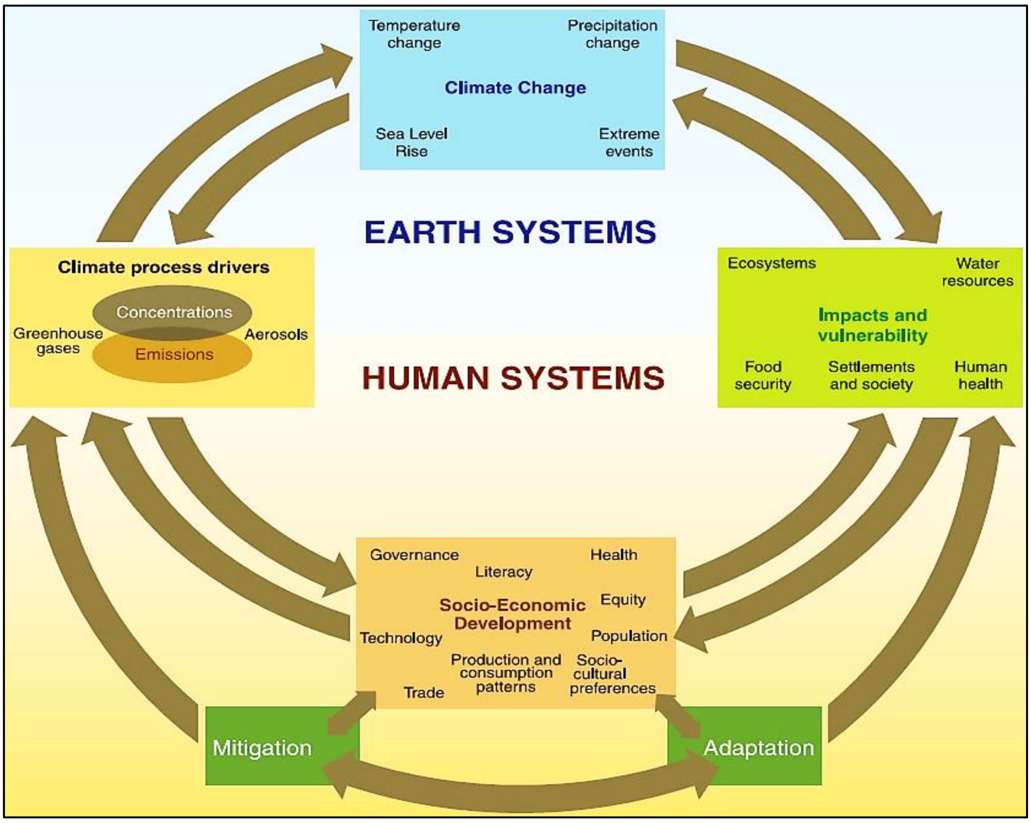
In terms of scales, food systems span institutional, informational, biophysical and cultural scales, to name but a few. These cross-level and cross-scale interactions add to the complexity of interactions and feedbacks, and also mean food systems are complex to govern.

0.15Theoretical Framework of the study

0.15.1 The Earth-Human system model

Theorization culminates in the Earth-Human Systems model that shows the interactions between climate change, impacts and vulnerabilities, adaptation and mitigation (socio-economic development) and drivers of the local and global climate system (Figure 0.8). Climate variability increases the frequency of meteorological and agricultural droughts, as well as an increase the frequency of short hydrological droughts. Climate change (long-term) negatively impacts food production systems and the functioning of ecosystem services, food security, human health and human settlements. This will affect adaptation and mitigation measure in terms of climate change governance, indigenous technological innovations, production and consumption patterns, socio-cultural practices, gender equality, population mobility, literacy rates, local economy and other adaptation strategies.

In line with the earth-human system framework, the Sendai Framework for Disaster Risk Reduction (2015-2030)was adopted at the Third UN World Conference in Sendai, Japan, on March 18, 2015.



Source: IPCC, 2007

Figure 0. 8: Earth–human systems in relation to natural and anthropogenic drivers of climate change impacts and vulnerability

The Sendai Framework is the successor instrument to the Hyogo Framework for Action-HFA (2005-2015). The Hyogo Framework was designed to promote the integration of risk reduction associated with existing climate variability and future climate change into strategies for the reduction of disaster risk and adaptation to climate change. This included identification of climate related disaster risks, design of specific risk reduction measures and an improved and routine use of climate risk information by planners and other decision-makers. Evidence indicates that exposure of persons and assets in all countries has increased faster than vulnerability has decreased, thus generating new risks and a steady rise in climate- related losses, with a significant economic, social, health, cultural and environmental impact in the short, medium and long term, especially at local community levels (United Nations Office for Disaster Risk Reduction–UNISDR, 2015). Recurring small-scale disasters and slow-onset disasters particularly affect communities, households and small and medium-sized enterprises, constituting a high percentage of all losses.

In developing countries, where the mortality and economic losses from disasters are disproportionately higher and faced with increasing levels of possible hidden costs and challenges in order to meet financial and other obligations. Enhanced work to reduce exposure and vulnerability, thus preventing new disaster risks and accountability for disaster risk creation are needed at all levels. More dedicated action needs to be focused on tackling underlying disaster risk drivers, such as the consequences of climate variability and change, poverty and inequality, unplanned and rapid urbanization, poor land management and compounding factors such as demographic change, weak institutional arrangements, non-risk-informed policies, lack of regulation and incentives for private disaster risk reduction investment, limited availability of technology, unsustainable uses of natural resources and declining ecosystem services(International Strategy for Disaster Reduction–ISDR, 2005). It is necessary to continue strengthening good governance in climate disaster risk reduction strategies at the local, national, regional and global levels and improving preparedness and coordination for disaster response, rehabilitation and reconstruction, and to use post-disaster recovery and reconstruction to ‘build back better’, supported by strengthened modalities of local, national and international cooperation.

0.15.2 Thomas Malthus theory of population growth and food supply

The theory is derived from the assumption that food insecurity is the result of a decline in food availability. This approach is based on the relationship between population growth and the ability of humans to confront scarcity of food and natural resources, which has dominated the literature on food security (Malthus 1798). Indeed, when a country makes the transition from agriculture to industry, it faces either the industry's environmental effects as well as problems generated by urbanization and demographic change. Malthus (1798) suggested that population expansion follows a geometric progression whereas food supply follows an arithmetic progression, and concludes that population growth outstrips the earth's ability to provide enough means of subsistence for the population. Neo-Malthusian authors (Ehrlich and Ehrlich, 1991; Ophuls and Boyan 1992) concluded that population growth is a threat to food security because it leads to a decrease in food availability. This decrease is intensified by problems of access and utilization of food stuffs, which are exacerbated by the increasing scarcity. Food availability is at the core of environmentalism and needs to conserve resources. Therefore, sustainable methods of food production and economic development are essential.

0.15.3 Esther Boserup's Theory of Agricultural Intensification

Contrary to neo-Malthusians, several authors believe that technology and human ingenuity have always adequately confronted existing scarcities and will continue to do so in the future. Boserup (1965) showed that developing countries address urbanization problems and population growth by adapting new technologies and strategies of land-use intensification. In addition to technology, some authors take into account political and economic actions in the relationship between population growth and food security.

0.15.4 The theory of environmental determinism

Determinism or environmental determinism is based on the basic tenet of "earth made man" and pays more attention on the complete control of physical environment on man and his activities. This concept stresses the influence of the environment on man and his activities and treats man as Subordinate to nature (environment). Friedrich Ratzel (1882) and Semple (1911) cited in Adhikari (2010) were the main propagators of environmental determinism. Ratzel, a German Geographer of nineteenth century was the founder of human geography. He stressed upon the influence of the physical environment on man as he reckoned mans as the end product of evolution. His first volume of Anthropogeography was designed to seek the cause of human phenomena in the natural environment. "Ratzel's approach was influenced by the theory that the physical environment plays an active role in the evolution of life forms on the earth's surface. This was one of the best ideas of Darwininan theory of evolution." Ditshit (2006) under the impact of this approach, man began to be viewed somewhat like an organism that could be studied in the way that biologist attempt to study the organism in nature in relation to the physical environment. But Zatzel latter modified his deterministic mode of thought in his second volume of Anthropogeographie (1991) in which he discussed various phenomena in terms of physical conditions and historical and cultural setting. American Geographer Semple was discipline of Ratzel. She was indoctrinated by her famous book, influence of Geographic Environment (1911) and expounded the causes of environmental determinism vigorously. She started her book with the conviction and assets. “Man is a product of the earth’s surface. This means not merely that he is a child of the earth, dust or her clust, but that the earth has mothered him, fed him, set him tasks, directed his thoughts, she has entered into his bone and tissues into his mind and soul”

This asserts the fact that the natural environment dictates the cause of culture. In this model, human society is restricted to a range of outcomes or events by a particular environmental parameter. Therefore, this study relates directly to rainfall and temperature variability as environmental factors that are independent and are controlling agriculture. This is clearly the situation with maize production in Bamenda II Sub Division that has been for the past decades been impacted adversely by rainfall and temperature variability. In the determinist’s view, people response to the actions and initiatives of nature considering climate as the most important factor of the physical world. This assertion relates climate as a factor that influence all that man does especially rain-fed agriculture (maize production) which is what this write-up seeks to address.

0.15.5 The theory of environmental possibilism

The doctrine of possibilism by Paul Vidal De La Blanche tries to explain the relationship of human being with the environment in different ways. It puts human at a higher level and regards it as an active agent. It is a principle which claims that environment provides opportunities and man being an economic man, chooses from these possibilities. Febvre (1932) in “A geographical Introduction to History” stated “there are no necessities, but everywhere possibilities and man as a master of these possibilities is the judge of their use”. The roots of possibilism can be traced back to the works of Plato, Montesquieu in the 18 century.

In the 19th century George Perkin Marsh and Kirchoff made an attempt to put forward a non-deterministic approach to human geography. They focused on man himself. It was only in the latter half of the 19th century that under the leadership of Vidal De La Blanche 1845-1918) (cited in Dikshit, 2010), a possbilistic view of man-environment developed. The focus of the philosophy was ‘Nature has set boundaries and has provided possibilities for human settlement, but the way a person responds to these conditions or adjust it depends on the traditional way of life”

Vidal rejected the concept of material determinism and advocated favourability. He even rejected Durkheim’s opinion of human geography as social morphology and rather insisted that man was a partner and not a slave of the environment (Dikshit, 2010). He was critical of Darwininan Ratzelian heritage which proposed environmental determinism and put forth the concept of possibilism. To him, man was part of nature and therefore, its most active collaborator. To resolve this dichotomy he generated the concept of ‘genre de vie’. ‘Genre de vie’ (war of life) includes all activities, practices, and techniques that characterize the adaptation of a human group to the milieu – the natural surroundings of their habitat (Mercier, 2012).cited in Ditshit, (2010), Vidal pointed out that the same genre de vie had different interpretations for various human groups. Thus, his works gave a sound methodological as well as a philosophical foundation for the doctrine of possibilism. This growth somewhat weakened the hold of Darwinian Determinism within the geographical thinking. In the twentieth century, possibilism got stronghold after the publication of Vidal rejected the concept of material determinism and advocated favourability. He even rejected Durkheim’s opinion of human geography as social morphology rather insisted that man was a partner and not a slave of the environment (Dikshit, 2010). He was critical of Darwinian Ratzelian heritage which proposed environmental determinism and put forth the concept of possibilism. He sought a scheme for understanding the interaction of nature and culture that eschewed both environmental determinism and radical possibilism to seek answers or solution for the dichotomy between the human and the environment. He vehemently rejected the idea that society and nature stood out as adversaries in the human-nature confrontation. For him, the man was part of nature and therefore, its most active collaborator. To resolve this dichotomy, he generated the concept of ‘genre de vie’. ‘Genre de vie’ (way of life) includes all activities, practices, and techniques that characterize the adaptation of a human group to the milieu – the natural surroundings of their habitat (Mercier, 2009). Vidal pointed out that the same genre de vie had different interpretations for various human groups. Thus, his works gave a sound methodological as well as a philosophical foundation for the doctrine of possibilism. This growth somewhat weakened the hold of Darwinian Determinism within the geographical thinking. This made posibilism to get stronghold in the 20th century. For instance, in the hot desert zone(s), man still practice carry out agriculture through his technique of irrigation of irrigation. This implies the role of environment in determining is minimised. This theory clearly relate to this study area in explaining the fact that, rainfall and temperature variability as environmental factors can be minimized by man through the use of technology to boost maize production. Since maize can be planted anywhere and at any time without any effect on productivity, man can use his intelligence and technology to overcome the impact of climate variability.

0.16 Research Methodology

The methodology employed in this study is a hypothetico-deductive approach with the specific hypotheses as the focus, subjected to verification at the end of each result chapter. This method made use of various research methods and techniques that were mainly concerned with data collection, treatment and presentation. Libraries and online resources were consulted to collect information on the effect of climate variation on food security. Among them were libraries of the University of Yaounde I, The University of Bamenda, the archives of the Bamenda II Council, and the Sub-divisional Delegation for Agriculture and Rural Development Bamenda II. The Ministry of Agriculture, Ministry of Scientific Research, NGOs, and other related offices and institutions were visited in order to get more data related to the agricultural system and the various strategies they adopt toward climate variability and change to ensure food security. This paved the way for fieldwork to carefully observe and identify how climate variation (rainfall and temperature patterns) affect maize yields in Bamenda II Sub-division which is the major parameter of food security. During this phase, farmers, council authorities, and resource persons in Bamenda II Sub-division were contacted and the facts collected were either through, field observation, administration of questionnaires, focus group discussion and interviews.

0.16.1 Sources of data collection

The data collected for this research work came from two main sources which were primary and secondary sources.

0.16.1.1 Secondary sources of data

Many documents were consulted to obtain secondary data. The data obtained was largely qualitative data and was gotten mostly through literature review. By consultation and systematically exploiting the following documents; annual reports, registers, theses, dissertations, articles, textbooks, topographic maps, aerial photographs, and satellite images published and unpublished documents on climate variation and food security while making use of some related websites on food security. Internet materials were downloaded in a flash disk and exploited. All documents were exploited by analysing ideas of existing authors and researchers' works on the topic while making some modifications. These consultations were realized from libraries, research institutions, and internet exploration. Libraries of the University of Yaoundé I particularly those of the Faculty of Arts, Letters and Social Sciences (FALSS) and the Regional School of Agriculture Bambili were visited. The intention was to find out what has already been done in the domain of climate variation with food security so as to know the gaps to be filled by our study and equally to gather more relevant data.

Bamenda II Council Development Plan (CDP) was also consulted to get data patterning to agriculture and economic activities of Bamenda II Sub-division. Specialized research centers of IRAD in Nkolbison, and specialized administrative service center of Bamenda II Council area (IRAD Mankon) alongside the Sub-divisional services for Agricultural Statistic and Survey were visited to obtain data relating to agricultural output and some adaptation strategies put in place. Lastly, organizations were also visited such as the food and Agriculture Organization of the United Nations to see what has been done to ensure food security in other areas of the world. All this was done to get information on climate variation in Bamenda II Sub-division to see the extent to which it has affected the agricultural sector, the main determinant of food security.

The main climatic data obtained was rainfall (1963-2021) and temperature (1975-2021) from the North West Meteorological Service at the Regional Delegation of Transport. This was to ensure that the climatic data were consistent and coherent. It consisted of monthly and inter-annual rainfall and temperature, number of rainy day used to show the relationship existing between maize production and rainfall/temperature variation. The main climatic parameters that determine maize production in Bamenda II and the Bamenda Highlands as a whole is the practice of rain-fed production systems. Furthermore, the data were subjected to decadal and inter-annual patterns, and anomalies which are observed over time, and their influence on maize production. Two indices, namely the Standardized Precipitation Index (SPI) and Cumulative Departure Index (CDI) were used to prove that rainfall is getting more unreliable for maize production to ensure food security in Bamenda II.

0.16.1.2 Primary data collection

Trips were organized to the field; the first was for familiarization with the study area. Primary data for the study was gotten through fieldwork and was largely quantitative in character. It comprised of data obtained from direct contact with resource persons of the Bamenda II Council, IRAD Mankon, and direct observation on the field through visits in the main maize production zones in Chomba, Nsongwa, Mbatu, Mulang, Ntankah and Mukwebuh. From these visits, data were obtained through interviews, focused group discussions, questionnaire administration to farmers and households through convenient random sampling alongside direct field observations. This pilot field study helped to initiate the process of data collection. The second tour continued with data assortment which took quite a long because of the sociopolitical condition of the region. Field data was collected in two phases, which were the early planting periods, and the harvesting periods. The first coincided with the beginning of the rainy season when planting takes place, while the second corresponded with the harvesting period in August and September and the second farming season.

0.16.2. Field observations

With regards to field observation, areas were selected with a high rate of agricultural activity such as Chomba, Nsongwa, Mbatu, Mulang, Ntankah and Mukwebuh to observe the extent to which climate variation affects the quantity and quality maize produced. An appraisal of agricultural activities in the study area was made through participant and passive observations. During the observation phase, photos of landmark maize production sites were taken. Participant observation gave a deeper understanding of certain practices. This was to understand issues linked directly or indirectly to climate variation.The fieldwork was carried out from the month of March to December because Bamenda II has two maize cultivation seasons being the wet season from mid-March/April to October and the dry season from November to mid-March.

0.16.3 Interviews

Five interviews were conducted with targeted resource persons and officials for an insight on maize production, climate variation, and how this variation affects food security. This involved the Divisional and Sub-division Delegate of Agriculture and Rural Development in Bamenda II, Mayor of Bamenda II Sub-division, Director of IRAD Mankon, and some major farmers of the community not forgetting local authorities in this area such as the quarter heads of Chomba, Nsongwa, Mbatu, Mulang, Ntankah and Mukwebuh who gave insights on climate variation and how it affects food production in general and maize in particular, adaptation and the culture of the people, and their various feeding habits. This gave a wider knowledge and concrete information on how food security has been affected due to variation of maize output caused by rainfall and temperature variations.

0.16.4 Focus group discussions

Focus group discussions were organized to collect primary data from the field. This was carried out in villages and was mostly during gatherings such as njangi, cultural, and in churches. It was made up of mostly farmers, and those who sell foodstuff in the various local markets in Bamenda II Sub-division. It had a minimum of seven persons and a maximum of ten persons. During group discussion, issues discussed were mostly based on the patterns of rainfall, and how it affects maize cultivation which inturn affects food security, while, identifying strategies used to fight against extreme climatic conditions such as prolonged dry season. At the same time, looking at how such negative effects, influences maize cultivation methods used in Bamenda II. However, some aspects patterning to food preservation and the affordability of food at the house whole level were equally discussed. A checklist was developed in order to keep track of the topics for the discussion and exploration with the groups.

0.16.5 Population for the study

The total population of Bamenda II in 2022 is projected at 281,974. From the entire study area, six villages were selected for this study (Chomba, Nsongwa, Mbatu, Mulang, Ntankah and Mukwebuh). The choice of these villages is anchored on the fact that they are the main agricultural zones. The total population for these five villages stands at 24,235 inhabitants.

0.16.6 Sampling technique

The sample size for this study stood at 5%, gotten from the total number of households in each village using the formula:

X*5/100

X= number of households

5%= sample size chosen

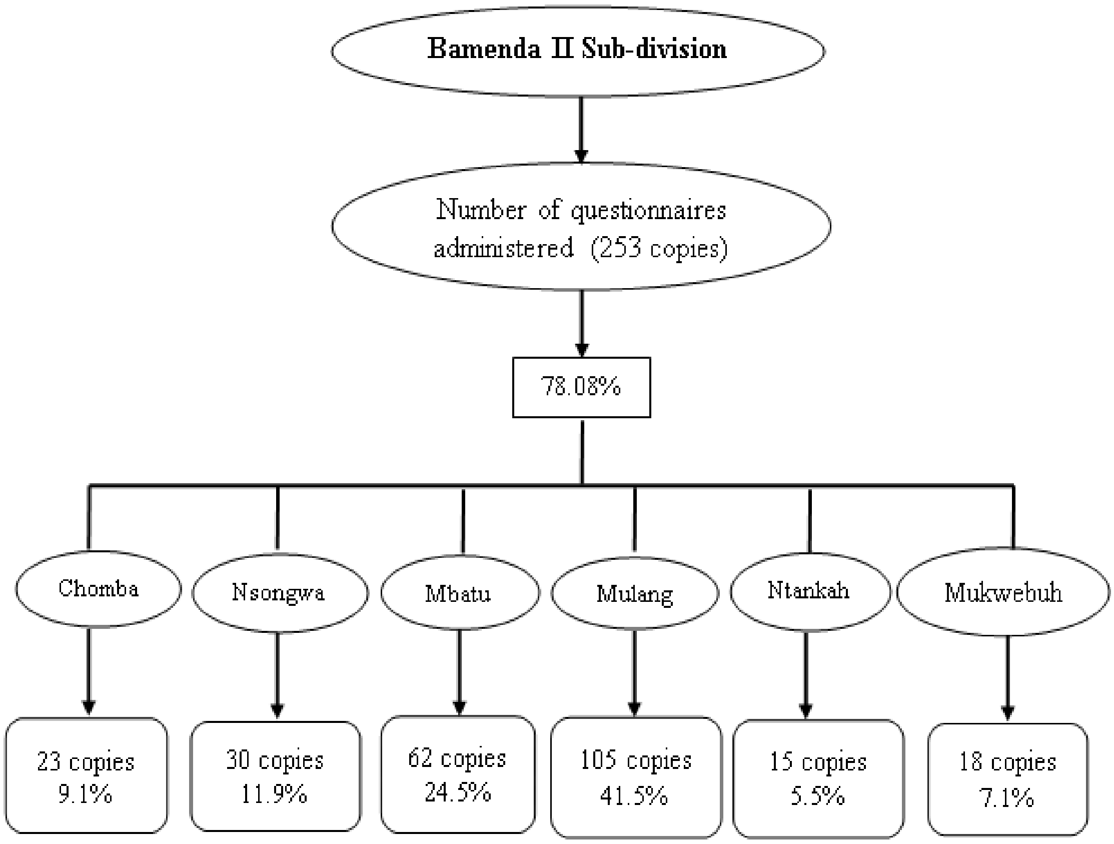
Computing a 5% sample size from a populationof 24,235 to giving a total of 253questionnaire retrieved and treated for this study (Table 0.3).

Table 0.3: Distribution of questionnaires per village

Village	Population*	Questionnaires** administered	Questionnaires** retrieved	Percentage retrieved
Chomba	2369	27	23	9.1
Nsongwa	2216	37	30	11.9
Mbatu	6245	70	62	24.5
Mulang	10546	115	105	41.5
Ntankah	1535	20	15	5.9
Mukwebuh	1324	25	18	7.1
Total	24235	324	253	100

Source: *Bamenda II Council, **Fieldwork, 2022

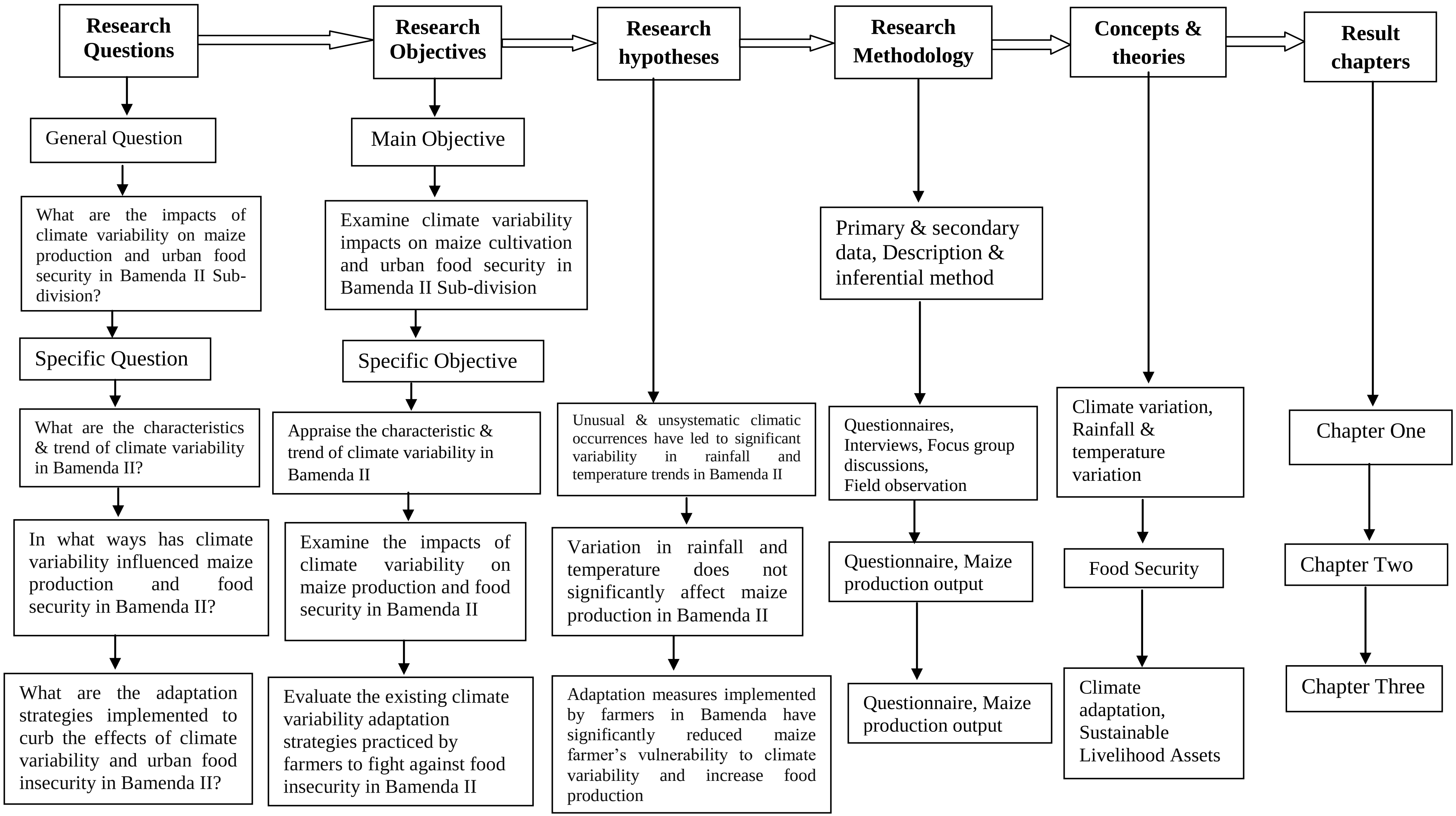
The researcher was able to know the total number of copies of the questionnaire to be taken to the field for administration. The administration of questionnaire was done through the systematic random sampling approach where copies were attributed to those who were available and ready to participate in the study because of the ongoing insecurity problem. Based on 5% sample size, 23 copies were administered in Chomba, Nsongwa (30), Mbatu (62), Mulang (105), Ntanka (15) and Mukwebuh (18) as shown on Figure 0.9.



Source: Author's conception, 2022

Figure 0. 9: Spatial distribution of effective respondent in the various villages of Bamenda II Sub-division

The research design has been conceived in a tabular form and presented to capture the research questions, objectives, hypothesis methodology, concepts, theories and the chapter layout (Figure 0.10).



Source: Author's conception, 2022

Figure 0. 10: Synthesis flow chat

0.16.7 Data treatment and presentation

Different types of data were collected, which implies different treatment methods. The various types of data principally consisted of quantitative and qualitative data which embodied in questionnaires, maize production data, rainfall data and temperature data. In order to better analyze the data collected from the field, descriptive and inferential statistical tools were used. Data obtained were treated differently and presented in the form of graphics, figures and tables.

Both inferential and descriptive statistics have been used in treating the data. The first specific hypothesis stated that 'unusual and unsystematic climatic occurrences have led to significant variability in rainfall and temperature trends in Bamenda II Sub-division'. This hypothesis was tested using a One-Way ANOVA. Time series were also used in presenting climatic data (inter-annual and decadal). Specific indices have also been used in expressing climate variability, namely Standardized Precipitation Index (SPI) and Cumulative Departure Index (CDI).

The independent variable for this study is climate. The elements of climate considered are rainfall and temperature. The dependent variables include agriculture in general and maize production. The dependent variables are a function of socio-economic factors such education and indigenous knowledge systems. Each variable was analyzed in detail with respect to its contribution to climate variability. Mean Annual, Inter-annual and Seasonal Variations; Measures of Standard Deviations, Variances and specifically, Coefficient of Variation (CV) for rainfall reliability was analyzed systematically. Decadal variations of all climatic elements for this study and specifically, percentage changes in rainfall and temperature. All decadal variations were treated as anomalies to establish trends, illustrated in graphs (time series analysis), fitted with R^2 and linear equations (Coefficient of Determination to show the percentage change of each climatic element).

Both qualitative and quantitative techniques were, thus, employed in data analysis. Rainfall and temperature influence the climate of the Western Highlands in general. To make sense out of these and to determine change over time, monthly means, annual means, mean annual anomalies, running means, decadal means, decadal anomalies, seasonal means, seasonal anomalies, annual, and decadal basis were calculated.

In the same vein, the Standardized Precipitation Index (SPI) was calculated. The SPI is a tool which was developed primarily for defining and monitoring drought. It allows an analyst to determine the rarity of a drought at a given time scale (temporal resolution) of interest for any rainfall station with historic data. It can also be used to determine periods of anomalously wet events. Conceptually, SPI is the number of standard deviations by which the precipitation values recorded for a location would differ from the mean over certain periods. In statistical terms, the SPI is equivalent to the Z-score.

$\mathrm{Z-score} = \mathrm{x} - \frac{\mu}{\delta}$ ………………..………………………..………… (McKee et al., 1993)

Where:

Z-score expresses the x score's distance from the mean (μ) in standard deviation (δ) units.

Statistically, the SPI is based on the cumulative probability of a given rainfall event occurring at a station. SPI was used to assess the occurrence of drought incidents in the Bamenda II Sub-division. All anomaly graphs generated from the data were fitted with trend lines and linear equations. The trend lines indicate increase or decrease in the elements under study.

Rainfall Seasonality Index (SI) and Standardized Precipitation Index (SPI) were employed to assess the vulnerability of the agro-hydrological system to climate variation. Both SPI and SI are dimensionless. Consistency and relationships between these climatic elements was analyzed systematically. All inter-annual and seasonal variations were treated as anomalies to establish trends, illustrated in graphs, fitted with R^2 and linear equations to show variations in each climatic element. Other measures of central tendencies for these weather elements included Standard Deviation (σ), Variance and Coefficient of Variation (CV). CV is calculated thus:

$$\sigma = \frac{\sqrt{\Sigma(\mathrm{Y} - \bar{\mathrm{Y}})}^2}{\mathrm{N}}$$

$$\mathrm{CV} = \sigma * \frac{100}{\bar{\mathrm{Y}}}$$

Where: $\bar{\mathrm{Y}}$ = mean

N = sample size

From these analyses, tables were generated to summarize climatic characteristics. The drought vulnerability for this study is assessed by reconstructing historical occurrence on a 12-months' time scale. Anomalies were calculated for all climatic elements analyzed for this study. Anomalies are calculated thus: $\frac{\text{Mean}}{\mu} * 100$

Climatic trends show fluctuations in both early growing season (EGS) and late growing season (LGS). To assess these fluctuations, rainfall Cumulative Departure Index (CDI) was used. CDI is expressed statistically as:

$\text{CDI} = \frac{\text{Ra}-\text{Rm}}{\text{SD}}$ …………………………….……………….. (Ayanlade et al., 2017)

Where:

CDI = Cumulative Departure Index

Ra = Actual rainfall for the growing season months (developed from mean monthly rainfall)

Rm = Mean rainfall for the growing season

SD = Standard Deviation of mean annual rainfall

The second specific hypothesis stated that variation in rainfall and temperature does not significantly affect maize production in Bamenda II Sub-division. This was verified using the Pearson Product Moment Correlation.

The third specific hypothesis stated that adaptation measures implemented by farmers in Bamenda II Sub-division have significantly reduced maize farmer's vulnerability to climate variability and increase food production. It was tested using a Linear Regression Model.

0.17 Plan of work

The general introduction of this work covers the background of the study, delimitation of the study, the problem statement, research questions, objectives, and hypotheses of the study. The literature review, concepts as well as theories related to the topic are equally examined in the general introduction. This section of work ends with the research methodology of the study.

This study is presented in three chapters. Chapter one investigates the variation of rainfall and temperature patterns and their impact on maize cultivation. The chapter analyses the people's perception of the changing environmental conditions. Also, analysis was done on rainfall and temperature trends of this area. In addition, the Standardized Precipitation Index and the Cumulative Departure Index were used to analyze measure precipitation anomalies to detect periods of meteorological and agricultural droughts. It equally looks at the regularities in rainfall events and their implications on agricultural in general and maize productivity in particular. The main goal of all this is to validate the first specific hypothesis.

Chapter two assesses maize production and implications for food security in Bamenda II Sub-division. While showing how the trend of agricultural production dropped due to climate variation resulting in the high use of fertilizers which is affecting the taste of staple food. This has contributed to some perturbation in the staple food even though food is readily available. The chapter equally measures the degree and magnitude of food insecurity and the various drivers responsible. This was done in order to validate the second specific hypothesis.

Chapter three expounds on climate adaptation strategies and sustainable livelihood assets for food security. The data collected, presented, analyzed, and interpreted helped in the validation of the third specific hypothesis.

CHAPTER ONE

CLIMATE VARIABILITY AND CHANGE IN BAMENDA II SUB-DIVISION

1.0 Introduction

This chapter appraises the characteristic and trend of climate variability in Bamenda II. It is guided by the hypothesis that unusual and unsystematic climatic occurrences have led to significant variability in rainfall and temperature trends. The sub-headings treated in this chapter include the perceived magnitude of climate variability in Bamenda II, sources of climate information, recent changes in climatic dynamics, perceived temperature and rainfall changes, as well as actual rainfall and temperature variability based on meteorological data from the North West Service for Meteorology at the Regional Delegation of Transport. From the meteorological data, inter-annual and decadal trends are established. The trend of the growing season has been evaluated using the Cumulative Departure Index (CDI). Rainfall reliability (Coefficient of Variation-CV) has also been established. The CV is complemented by the Standardized Precipitation Index (SPI). The chapter wraps with observed local drivers of climate variability and their effects on agriculture as a whole and maize production in particular.

1.1 Characteristics of the sampled population

The various demographic characteristics of the sampled population included gender, marital status, age group, family size, education level, neighborhood and occupation (Table 1.1). It can be observed that a greater proportion of the respondents were the female gender (61.3%) while the male gender (38.7%) made up the least proportion, indicating 22.6% difference between the male and female gender with respect to information on climate variability and change in Bamenda II Sub-division. The marital status of the sampled population also varied as 74.7% were married while the least proportion of 25.3% were single.

With respect to the age group, a greater proportion of the sampled population (60.1%) was those between the ages of 36 to 45 years while the least proportion was those between the ages of 26 – 34 years (7.1%).

The education level of the sampled population influenced their understanding of climate variability and change as educated people understood the study problem more than the uneducated. Greater proportions were holders of the FSLC (73.9%) while the least proportion were holders of the GCE A/L (9.1%). Holders of the GCE A/L especially on field related to environmental issues understood the study problem more than holders of the FSLC.

Table 1.1: Characteristics of the sampled population

Variables	Frequency	%	Variables	Frequency	%
Sex			10+	45	17.8
Male	98	38.7	**Education**		
Female	155	61.3	FSLC	187	73.9
Marital status			GCE O/L	43	17.0
Single	64	25.3	GCE A/L	23	9.1
Married	189	74.7	**Neighbourhood**		
Age group			Chomba	23	9.1
<25	34	13.4	Nsongwa	30	11.9
26-34	18	7.1	Mbatu	62	24.5
36-45	152	60.1	Mulang	105	41.5
46-55	25	9.9	Ntankah	15	5.9
55+	24	9.5	Mukwebuh	18	7.1
Family size			**Occupation**		
1-3	51	20.2	Farming	236	93.3
4-6	87	34.4	Business	8	3.2
7-9	70	27.7	Driver	9	3.6

Source: Fieldwork, May 2022

Some occupations like farming are more exposed to trends in climate variability and change than some occupations like driving. In terms of occupation, a greater proportion of the sampled population were farmers (93.3%) while those involved in business made up the least proportion (3.2%).

Gender of the household head is significant and positively connected with the likelihood of adopting indigenous environmental knowledge systems in agricultural decision-making. Male-headed households are associated more with indigenous soil and water conservation techniques by reading weather signs than female-headed households (Ajak et al., 2018). Such male-headed households are more likely to get skills and information about new strategies in soil and water management than female-headed households who have inadequate access to information (Perez et al., 2015).

Educational attainment is considered as a main key determinant of indigenous perception of climate variability and changing environmental conditions. The population with low levels of education rely more on indigenous knowledge in appreciating weather events. Low levels of education also entail little or no understanding of scientific weather events, so, they rely indigenous environmental knowledge. According to Huda et al., (2016) socio-demographic correlates like education play an important an important role in climate change adaptation. The inability of most community members to read and write is a strong indicator of a people's receptivity to new adaptation strategies. This is justified by the attitudes of the least educated respondents towards adaptation strategies.

1.2 Climate Variability in Bamenda II Sub-division

The various aspects discussed under climate variability in Bamenda II Sub-division include, magnitude of climate variability in Bamenda II, sources of climate information and recent changes in climate dynamics.

1.2.1 Magnitude of climate variability in Bamenda II

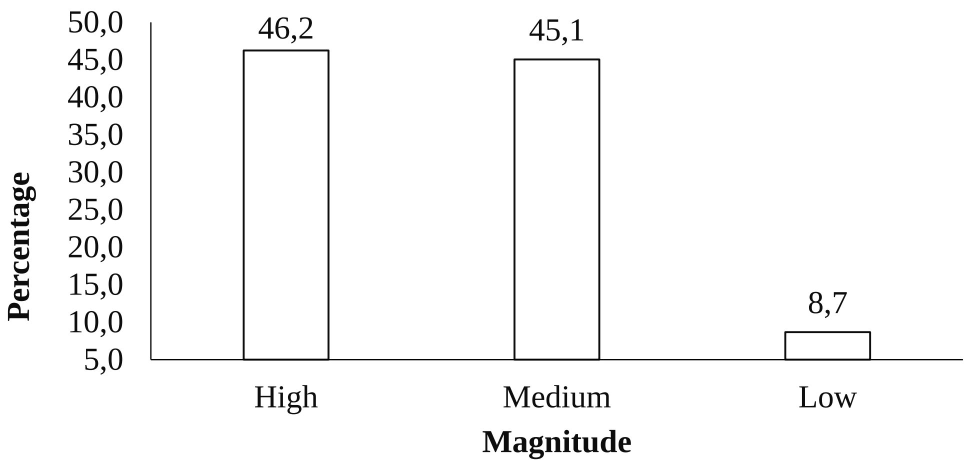
The magnitude of climate variability varied between the Chomba, Nsongwa, Mbatu, Mulang, Ntankah and Mukwebuh (Table 1.2).

Table 1.2: Magnitude of climate variability in Bamenda II Sub-division

Location	High		Medium		Low	
	F	%	F	%	F	%
Chomba	11	9.40	10	8.77	2	9.09
Nsongwa	15	12.82	12	10.53	3	13.64
Mbatu	28	23.93	29	25.44	5	22.73
Mulang	52	44.44	43	37.72	10	45.45
Ntankah	5	4.27	9	7.89	1	4.55
Mukwebuh	6	5.13	11	9.65	1	4.55
Total	**117**	**100**	**114**	**100**	**22**	**100**

Source: Fieldwork, May 2022

The magnitude of climate variability and change is high in Mulang (44.44%) than others neighborhoods. According to the IPCC (2007), the extent of climate variability effects on individual regions will vary over time and with the ability of different societal and environmental systems to mitigate or adapt to change. The IPCC (2014) predicted that increases in global mean temperature of less than 1.8 to 5.4^{o}F (1 to 3^{o}C) above 1990 levels will produce beneficial impacts in some regions and harmful ones in others. Net annual costs will increase over time as global temperatures increase. Global climate is projected to continue to change over this century and beyond. The magnitude of climate change beyond the next few decades depends primarily on the amount of heat-trapping gases emitted globally, and how sensitive the Earth's climate is to those emissions (IPCC, 2013). The magnitude of climate variability was largely considered by the sampled population to be high (46.2%) and medium (45.1%) (Figure1.1).



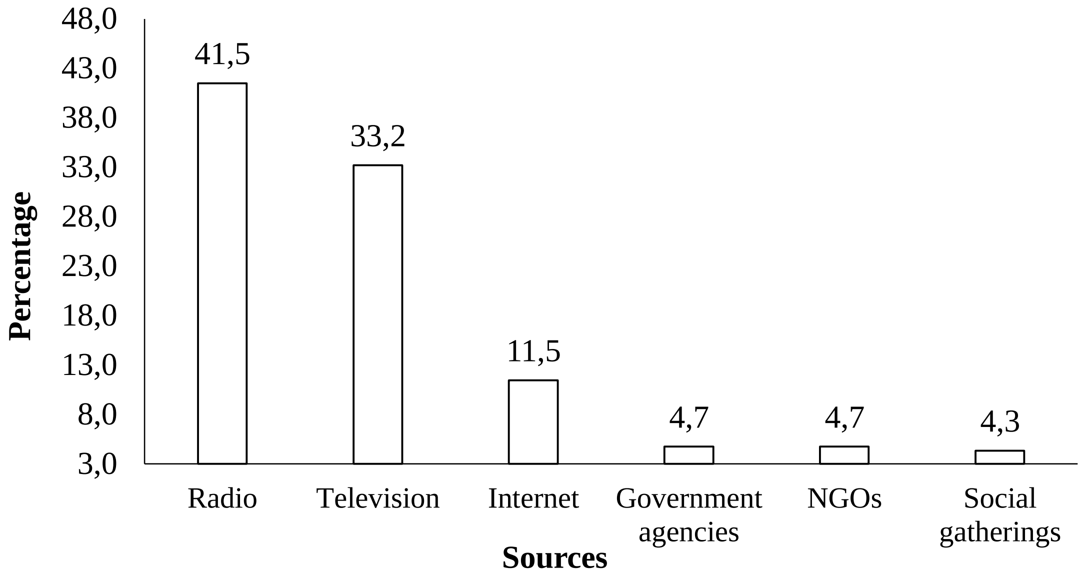
Source: Fieldwork, May 2022

Figure 1. 1.: Magnitude of climate variability in Bamenda II Sub-division

As far as the climate variability is concern, there are three main paradigms consisting a set of concepts on the nature of climate variability and they are the climate concept, the variability concept and the tragedy of common (Ayino et al., 2012).

1.2.2 Sources of climate information

In the period since the Industrial Revolution, human emissions of greenhouse gases from fossil fuel combustion, deforestation and agricultural practices have led to global warming and climate change (Stocker et al., 2019). Observed and anticipated changes in the climate include higher temperatures, changes in rainfall patterns, changes in the frequency and distribution of weather events such as droughts, storms, floods, heat waves, sea level rise and consequent impacts on human and natural systems. Many scientists argue that the impacts of climate variability will be devastating for natural and human systems and that climate variability poses an existential threat to human civilization. However, action to respond to climate variability has been slow. The various sources of climate information to the population of Bamenda II includes radio and television programs on climate, internet websites, government agencies through the Ministry of Environment, Protection of Nature and Sustainable Development, NGOs and social gatherings especially those on agricultural development since agriculture is the main sector affected by climate variability and change (Figure 1.2).



Source: Fieldwork, May 2022

Figure1. 2: Sources of climate information

The main source of climate information to the population of Bamenda II is the radio (41.5%) while the various television channels (33.2%) is also a major source of climate information. The main radio station that provides climate information is the Cameroon Radio and Television (CRTV).

Some of the radio stations also broadcast content in many local languages, thus giving them an added advantage in terms of outreach (especially with the uneducated people) over the likes of TV, print and online. Various climate-environmental focused programs are broadcasted or published by the media houses (Table 1.3).

Table 1.3: Climate-environmental programs broadcasted by media houses in Bamenda

Media house	Programs
Sky Sports Community Radio	Sustainable World
City FM	Climate Change Today
CRTV North West	Wake Up Crew
Foundation Radio	Terra Nostra, Save the Earth
CBC Radio	Our Environment
NDEFCAM Radio	Nature watch, Weather Magazine
Viewpoint	Ecosystems protection
CY Blog	Climate change articles

Source: Tanwie et al., 2022: 245.

All the programs broadcasted by these media houses are relevant to famers in Bamenda II and beyond. Despite the proliferation of these programs, farmers still rely on indigenous weather systems.

Media is a major driving force that brings about change in diverse societies and the world in general by creating awareness on specific matters, thereby shaping public interests, opinions and ultimately government legislation (Davidson, 2013). It is the most influential and expeditious means of information conveyance (Prakash, 2016) and extremely significant in shaping people's perceptions of climate variability and change (Brulle et al., 2012). The content of information disseminated is seen as critical in influencing public outlook on who is responsible for climate change mitigation and adaptation (Liang et al., 2014). Akpanet al., (2012) reasoned that, "public action towards climate change will not begin until the public understands climate change and their place in the fight against it, especially in the area of forcing the authorities to make and execute meaningful policy about it". The media must, therefore, continually adopt a pro-active approach in raising environmental concerns for the masses and for government .A study in Ghana revealed that television and radio broadcasts were the major sources of weather information for smallholder farmers (Ndamani and Watanabe, 2015). In urban India, television is the primary climate change information source (Pandve et al., (2011).

1.2.3 Recent changes in climate dynamics

According to the World Meteorological Organization (2020), the global indicators of climate change and variability are Greenhouse Gas concentrations, increasing land and ocean temperatures, sea level rise, melting ice and glacier retreat and extreme weather which have impacts on socio-economic development, migration and displacement, food security in land and marine ecosystems. The climate action movement uses typical social movement tactics such as protests, rallies, civil disobedience and rhetoric to raise the profile of climate change and advocate for urgent action. The movement is very visible at international negotiations, both inside and outside the venues. This is because the population does not actually understand the signs or indicators of climate change (Aichele, 2018). The recent changes in climate variability in Bamenda II Sub-division are increase in temperature, longer rainy season, increase incidence of wind, decrease rainfall, increase in sunshine and longer dry season (Table 1.4).

Table 1.4: Recent changes in climate dynamics in Bamenda II

Neighbourhood	SA		A		SD		D		N	
	F	%	F	%	F	%	F	%	F	%
Increase in temperature										
Chomba	8	9.52	14	10.29	1	4.35	0	0.00	0	0.00
Nsongwa	11	13.10	14	10.29	3	13.04	2	33.33	0	0.00
Mbatu	22	26.19	32	23.53	6	26.09	1	16.67	1	25.00
Mulang	33	39.29	56	41.18	11	47.83	3	50.00	2	50.00
Ntankah	5	5.95	8	5.88	1	4.35	0	0.00	1	25.00
Mukwebuh	5	5.95	12	8.82	1	4.35	0	0.00	0	0.00
Longer rainy season										
Chomba	6	8.33	12	10.43	3	9.38	2	5.88	0	0
Nsongwa	8	11.11	12	10.43	4	12.50	6	17.65	0	0
Mbatu	17	23.61	28	24.35	9	28.13	8	23.53	0	0
Mulang	27	37.50	50	43.48	13	40.63	15	44.12	0	0
Ntankah	6	8.33	5	4.35	2	6.25	2	5.88	0	0
Mukwebuh	8	11.11	8	6.96	1	3.13	1	2.94	0	0
Increase incidence of wind										

Chomba	4	13.33	11	7.86	5	9.43	2	11.11	1	8.33
Nsongwa	4	13.33	17	12.14	5	9.43	2	11.11	2	16.67
Mbatu	7	23.33	34	24.29	14	26.42	4	22.22	3	25.00
Mulang	13	43.33	54	38.57	26	49.06	8	44.44	4	33.33
Ntankah	1	3.33	9	6.43	3	5.66	1	5.56	1	8.33
Mukwebuh	1	3.33	15	10.71	0	0.00	1	5.56	1	8.33
Decrease rainfall										
Chomba	5	10.42	6	7.69	6	8.45	0	0	6	13.04
Nsongwa	7	14.58	10	12.82	8	11.27	1	10	4	8.70
Mbatu	11	22.92	19	24.36	19	26.76	2	20	11	23.91
Mulang	18	37.50	32	41.03	28	39.44	6	60	21	45.65
Ntankah	3	6.25	4	5.13	5	7.04	1	10	2	4.35
Mukwebuh	4	8.33	7	8.97	5	7.04	0	0	2	4.35
Increase in sunshine										
Chomba	6	7.79	12	9.76	3	11.11	2	9.09	0	0
Nsongwa	11	14.29	13	10.57	4	14.81	2	9.09	0	0
Mbatu	20	25.97	30	24.39	6	22.22	5	22.73	1	25
Mulang	30	38.96	50	40.65	12	44.44	10	45.45	3	75
Ntankah	5	6.49	7	5.69	1	3.70	2	9.09	0	0
Mukwebuh	5	6.49	11	8.94	1	3.70	1	4.55	0	0
Longer dry season										
Chomba	8	8.60	6	8.45	7	10.61	0	0.00	2	11.76
Nsongwa	13	13.98	9	12.68	6	9.09	1	16.67	1	5.88
Mbatu	22	23.66	18	25.35	17	25.76	1	16.67	4	23.53
Mulang	38	40.86	28	39.44	26	39.39	3	50.00	10	58.82
Ntankah	5	5.38	4	5.63	5	7.58	1	16.67	0	0
Mukwebuh	7	7.53	6	8.45	5	7.58	0	0.00	0	0

SA: Strongly Agree, A: Agree, SD: Strongly Disagree, D: Disagree, N: Neutral

Source: Fieldwork, May 2022

Results from Table 1.4 revealed that increasing temperatures, longer rainy season (2021), general decreasing rainfall, intensive sunshine, and longer dry season are some indicators of climate variability in Bamenda. Less rainfall at the early growing season causes maize and other crops to wilt (photo 1.1).

Photo 1. 1: Wilting maize crop caused by rainfall deficiency in Mankon (April 2022)

This is an indicator of climate variability and change because there is less rainfall as compared to the past years. Water resources like streams and springs are continuously decreasing in size or drying up accompanied by longer dry spells which is an indicator of climate variability in Bamenda II Sub-division. The higher average temperature in the municipality is one of the indicators of climate variability. According to the World Meteorological Organization, 2020 was warmer as it experienced higher temperatures than the previous years, indicating that the climate is changing as average temperatures are increasing. Frequent floods in Mulang and other lowland parts of the Sub-division are also an indicator of the variable climate. Floods and wind incidence (plate 1.1) occur in periods of intense and prolonged rainfall which is also accelerating soil erosion.

Plate 1. 1: Wind and flood incidence on a maize farm in Mankon

The weather of Bamenda II Sub-division is highly unpredictable and characterized by late or early onset of rain and the rate has been increasing which is an indicator of climate variability and change.

1.3 Perception of temperature and rainfall changes over time

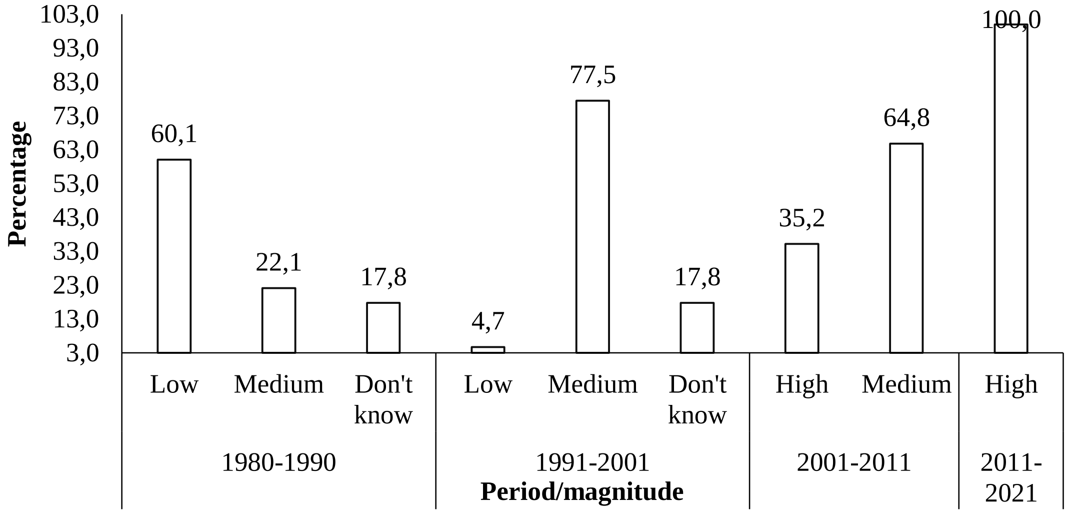
The population of Bamenda II had different perceptions about the variations in temperature and rainfall over time from 1980, 1991-2000, 2001-2010 and 2011 to 2021 (Table 1.5). The variations have been considered to be high, medium and low. Results revealed that before 1980, the variations in temperature in Bamenda II Sub-division according to respondent perception were mainly considered to a low (60.1%). From 1991 to 2001 (77.5%) and from 2001 to 2011 the variation was largely considered to be medium (64.8%) while temperatures are high (100%) in 2021 indicating climate variability in Bamenda II Sub-division.

Table 1.5: Perception of temperature and rainfall changes over time

Period	**Magnitude**	**Frequency**	**Percentage**
Temperature			
1980-1990	Low	152	60.1
	Medium	56	22.1
	Don't know	45	17.8
1991-2001	Low	12	4.7
	Medium	196	77.5
	Don't know	45	17.8
2001-2011	High	89	35.2
	Medium	164	64.8
2011-2021	High	253	100.0
Rainfall			
1980-1990	High	208	82.2
	Don't know	45	17.8
1991-2001	High	152	60.1
	Medium	56	22.1
	Don't know	45	17.8
2001-2011	Low	88	34.8
	Medium	165	65.2
2011-2021	Low	253	100.0

Source: Fieldwork, May 2022

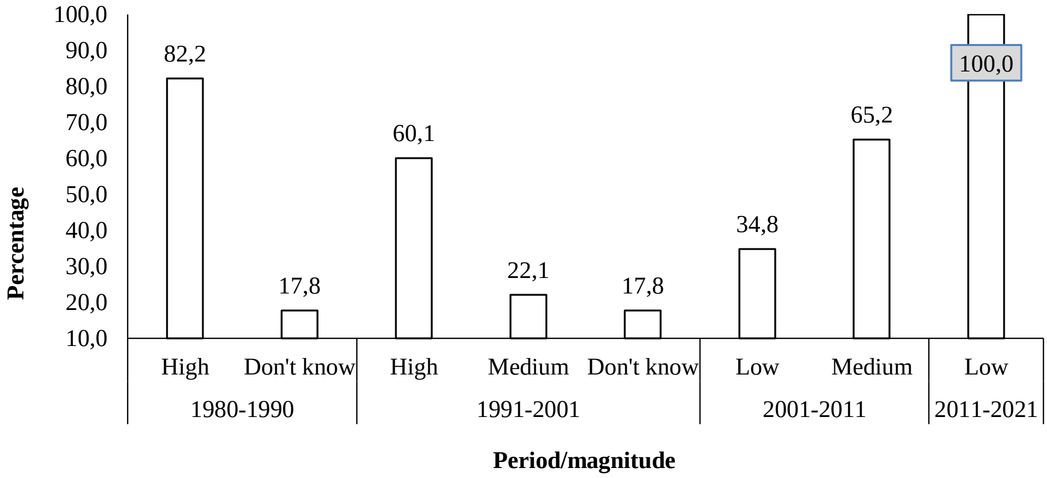
These variations also hold same for rainfall as rainfall is largely perceived to be low in 2021 (100%) (Figure 1.3).



Source: Fieldwork, May 2022

Figure 1. 3: Perceived temperature changes in Bamenda II

The variations in rainfall from 1990 to 2021 also indicate climate variability (Figure 1.4). The population perceived that rainfall was high during the 1980s to the 1990’s and has drastically reduced during the period 2011 to 2022.



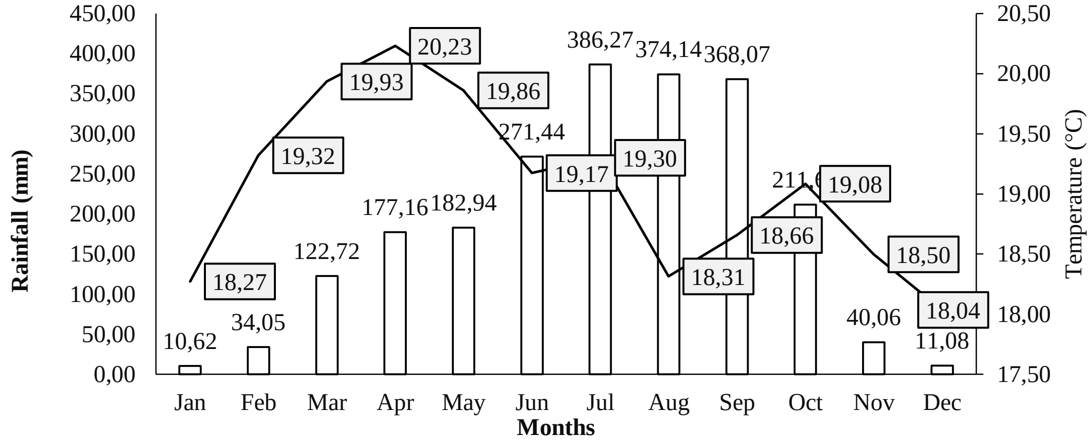
Source: Fieldwork, May 2022

Figure 1. 4: Perceived rainfall changes in Bamenda II

The subsequent discussions support the perceptions of the populations with scientific evidence (meteorological data) with actual climate variability using rainfall and temperature analysis.

1.4 Actual climate variability

Rainfall and temperature variations in Bamenda like in other tropical savannah locations have unique characteristics. Monthly rainfall amounts from January to a maximum in July to September, and decreases from October as the dry season sets in (Figure 1.5).



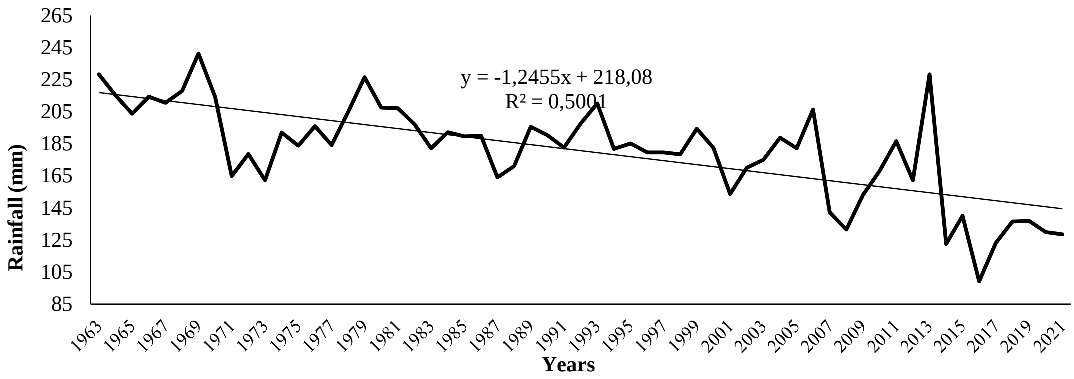
Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 5: Rainfall and temperature graph for Bamenda

According to Molua and Lambi (2006), there is a tendency towards increase in rainfall from February onwards in all parts of Cameroon, except the Northern Regions. Maximum mean monthly temperatures are recorded from March to April (transition for the wet season) as a result of rain clouds that retain much heat on the surface of the earth. The lowest temperatures are recorded from December to February because there are no clouds in the atmosphere to enhance a local greenhouse effect.

1.4.1 Inter-annual rainfall variability

The general rainfall pattern has been decreasing as perceived by the population. Rainfall data was collected from the Regional Meteorological Service for the North West Region from the period 1963-2019 and presented on Figure 1.6.



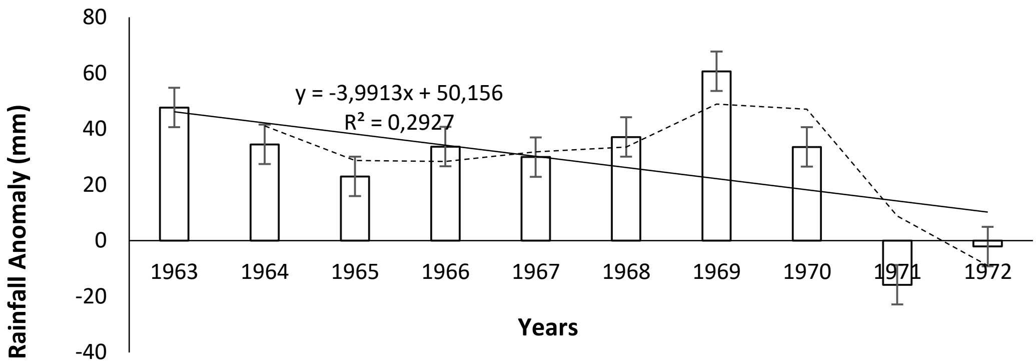
Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 6: Inter-annual rainfall trend for Bamenda (1963-2021)

The inter-annual rainfall is characterised by anomalies in the climate illustrating a highly fluctuating climate with a general decreasing trend in precipitation over the years.This fluctuation in climate tends to distort the agricultural and renders it less dependable for agricultural related activities. Rainfall has consistently been on the downward trend since 2014. Rainfall trends are better appreciated decadally.

1.4.2 Decadal rainfall trend analysis

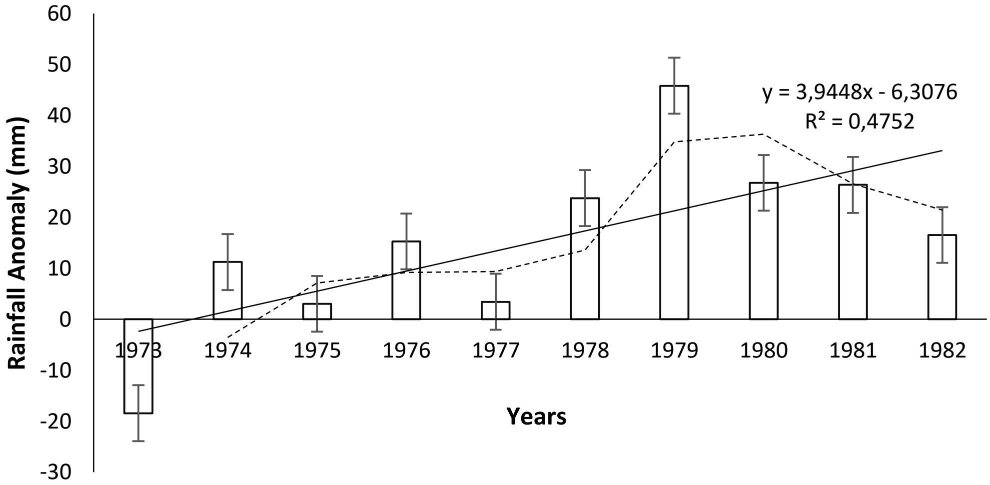
The decade 1963 to 1972 witnessed a decreasing rainfall trend, through the years 1963 to 1970 had positive rainfall value. The highest mean rainfall was recorded in 1969 (60.62 mm) (Figure 1.7).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 7: Inter-annual rainfall trend for Bamenda (1963-1972)

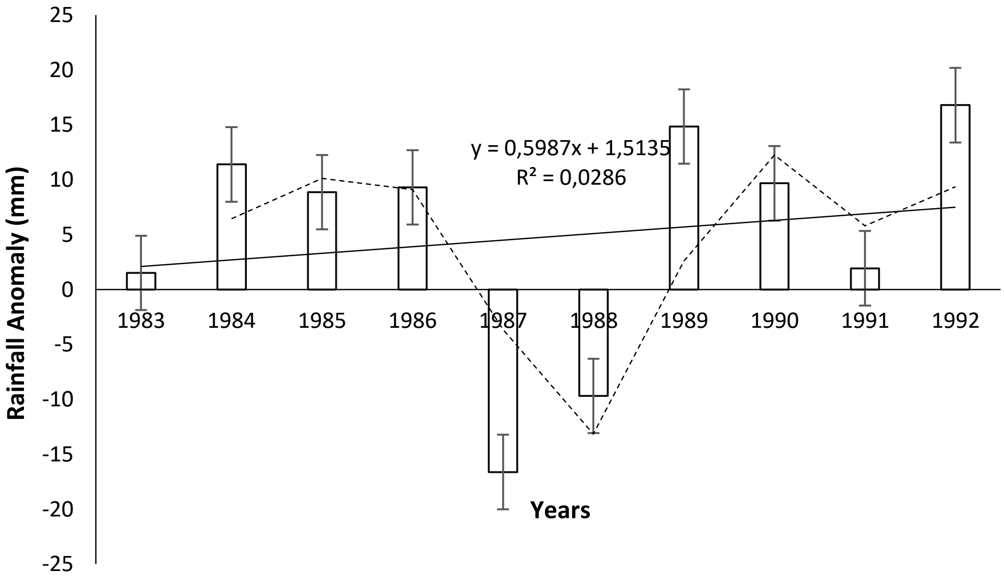
The years 1971-1972 recorded negative rainfall values below the average. This continued till 1973. However, the decade 1973 to 1982 witnessed an increasing rainfall trend (Figure 1.8).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 8: Inter-annual rainfall trend for Bamenda (1973-1982)

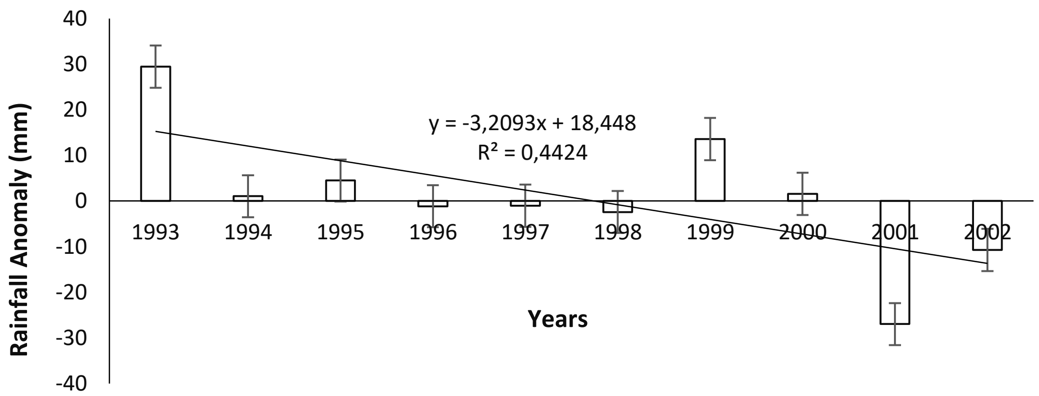
The highest rainfall this decade was recorded in 1979. From 1983 to 1992, rainfall was increasing slightly above the average. The highest rainfall was recorded in 1992, while the lowest records were noted in 1987 and 1988 (Figure 1.9).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 9: Inter-annual rainfall trend for Bamenda (1983-1992)

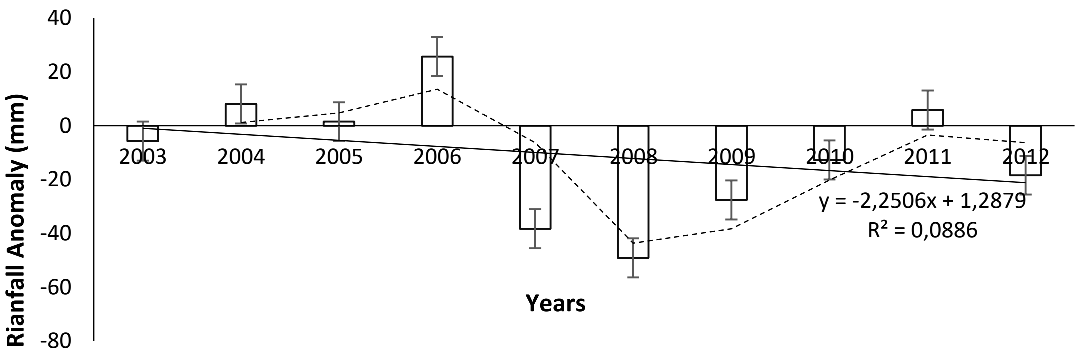
From 1993 to 2002, the rainfall trend had a steep nose dive. The highest rainfall was recorded in 1993 (Figure 1.10).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 10: Inter-annual rainfall trend for Bamenda (1993-2002)

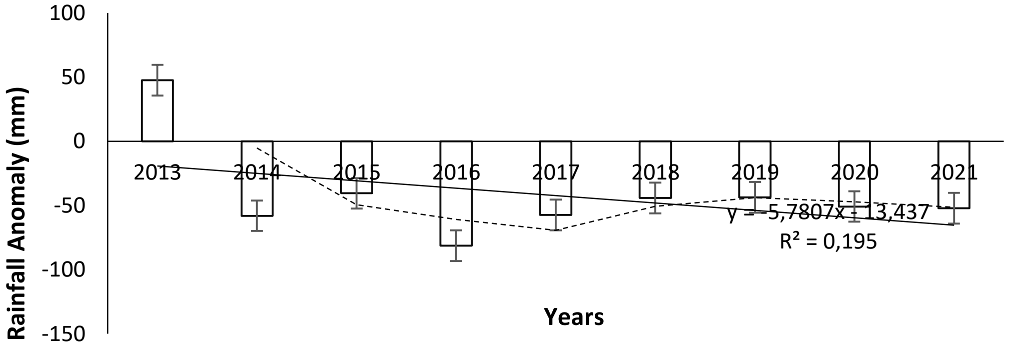
Years with negative anomalies were 1996-1998 and 2001-2002. Again, from 2003 to 2012, the rainfall trend was a decreasing trend below the average. The highest rainfallwas recorded in 2006 (Figure 1.11).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 11: Inter-annual rainfall trend for Bamenda (2003-2012)

Negative anomalies were recorded in 2003, 2007 to 2010 and 2012. The period 2013 to 2021 also witnessed decreasing rainfall below the average (Figure 1.1).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 12: Inter-annual rainfall trend for Bamenda (2013-2021

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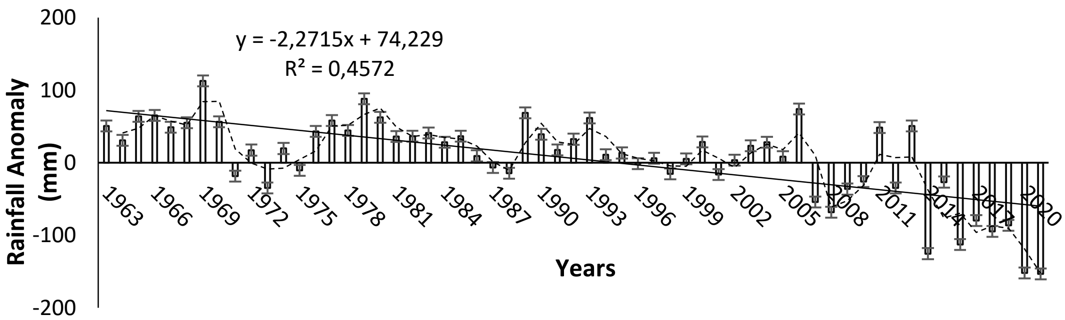
Rainfall has consistently been low since 2014. Such low rainfall has negative effects on water-sensitive crops grown in Bamenda II Sub-division like beans and maize.

1.4.3 Timing of the growing season (Cumulative Departure Index)

Climatic trends show fluctuations in both Early Growing Season (EGS) and Late Growing Season (LGS). To assess these fluctuations, rainfall Cumulative Departure Index (CDI) was used. The twists and oscillations in the rainfall pattern indicate that the growing season has been decreasing (Figure 1.13).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 13: Cumulative Departure Index for Bamenda

As noted in the inter-annual analysis, rainfall has consistently been declining since 1994, thereby exposing the crop production sector to an uncertain future. According to Kranz et al., (2008), rainfall thresholds of 85-275mm are required for a successful maize crop cycle in the tropical savannahs. Nkwemoh and Ndi (2017) affirmed that rainfall is highly unreliable at the beginning of the wet season in terms of number of rainy days to support tender crops that are highly susceptible and sensitive to the least changes in water requirements. Both evaporation and transpiration are driven by a tremendous drying force the atmosphere exerts on plant surfaces. The magnitude of daily evapotranspiration will vary with atmospheric conditions. For example, high solar radiation and air temperatures, low humidity, clear skies and high wind increase evapotranspiration, while cloudy, cool and calm days reduce evapotranspiration

(Kranz et al., 2008). Seasonal water use is also affected by growth stage, length of growing season, soil fertility, water availability and the interaction of these factors. Although the amount of daily water use by the crop will vary from season to season and location to location, it will generally follow a pattern of gradual increase of rainfall from the beginning of growing season, when the maize crop is sown to a maximum threshold of about 300mm during tasselling and development of cobs.

1.4.4 Rainfall Reliability

The mean annual rainfall for Bamenda stands at 128.49 mm, with a Standard Deviation of 29.7 and a Coefficient of Variation (CV) of 16.44% (reliable). It has been observed that rainfall has been reliable in Bamenda from 1963 to 2012 (Table 1.6).

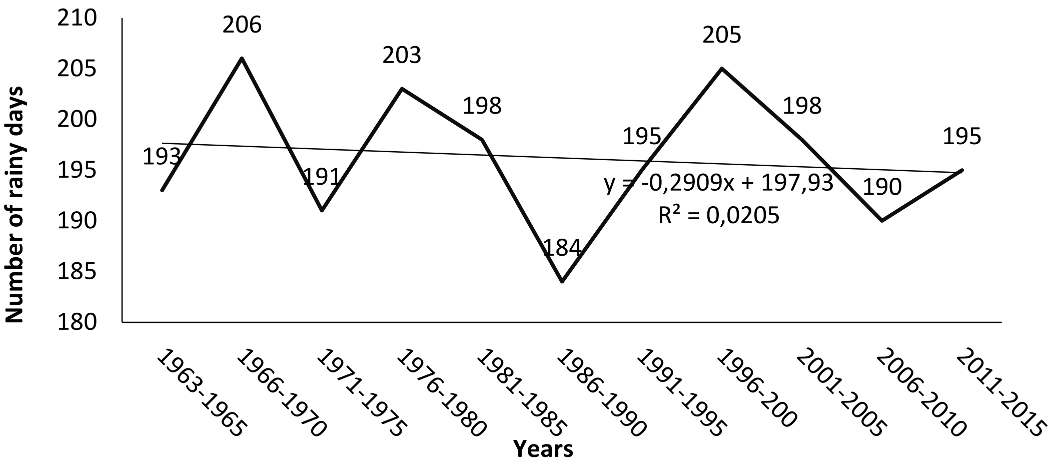
Table 1.6: Summary of rainfall decadal rainfall reliability in Bamenda

Periods	Mean(mm)	SD	CV (%)	Trend	Reliability
1963-1972	208.91	22.33	10.69	Decreasing above average	Reliable
1973-1982	196.1	17.32	8.83	Increasing above average	Reliable
1983-1992	185.51	10.72	5.78	Increasing above average	Reliable
1993-2002	181.5	14.6	8.04	Decreasing	Reliable
2003-2012	169.62	22.88	13.49	Decreasing below average	Reliable
2013-2021	138.37	35.85	25.91	Decreasing below average	Unreliable

Source: Computer from Figure 1.9-1.14

The long-term mean precipitation for a month, season or year hardly indicates the reliability with which given amounts of rainfall can be anticipated. This is relevant in the low latitudes where rainfall is highly variable from one year to another (Nieuwolt, 1975). The less variable rainfall is, the more reliable it is (Ayoade, 1988) because the index of variability is a measure of the degree of likelihood of the mean amount being replicated each year, season or month, depending on the period under study. Several measures of rainfall variability are commonly used as the Coefficient of Variation. This measure is more efficient provided that the data is normally distributed. Annual rainfall totals of more than 750 mm tend to be more normally distributed than mean seasonal and monthly totals (Ayoade, 1998). These variations directly affect the timing of the agricultural system in the tropics because they are rain-fed.

Despite the general reliability of rainfall in Bamenda, it has been observed that the number of rainy days has been decreasing (Figure 1.14).



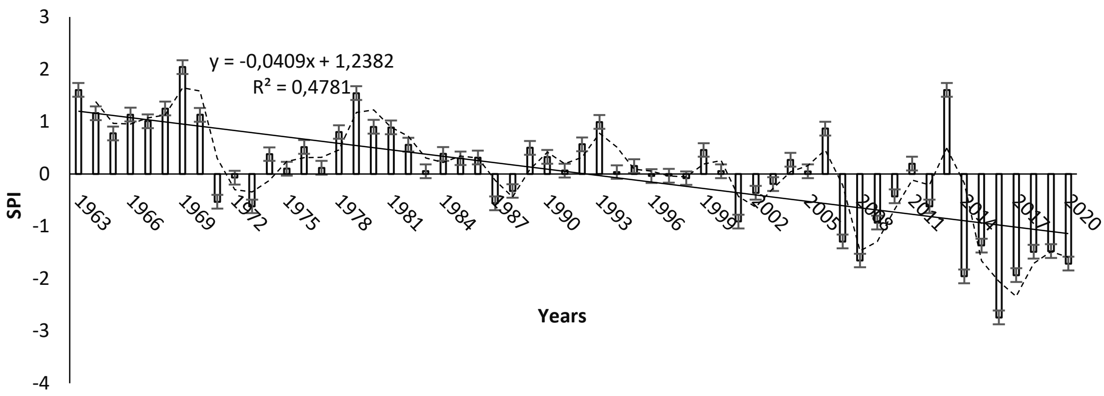
Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 14: Trend in number of rainy days (1963-2015)

The average number of rainy days has been oscillating, with a general decreasing trend, varying from 184 to 206 rainy days per year. The highest number of rainy days were recorded from 1966 to 1970 (206), while the least number of rainy days were noted from 1986 to 1990 (184). Fewer rainy days were also recorded from 2006 to 2010 (190). This decreasing number of rainy days is in line with the Cumulative Departure Index, which revealed that the growing season has been decreasing.

1.4.5 Standardized Precipitation Index valuation of rainfall reliability

Over the years, many drought indices have been developed. These ranged from simple indices such as percentage of normal precipitation and precipitation percentiles to more complicated indices such as the Palmer Drought Severity Index (PDSI) (World Meteorological Organization, 2012). Meteorologists in the USA realized that an index needs to be simple, easy to calculate and statistically relevant. The understanding that a meteorological drought has different impacts on groundwater, reservoir storage, soil moisture and stream flow led McKeeet al.,(1993) to develop the Standardized Precipitation Index (SPI). Precipitation is the only required input parameter. It is effective in analyzing wet and dry cycles. The SPI trend for Bamenda shows the same pattern of the inter-annual rainfall (declining) (Figure 1.17).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 15: Inter-annual Standardized Precipitation Index for Bamenda (1963-2021)

As observed, the period 2014 to 2021 has shown consistent rainfall deficits, making rainfall unreliable for profitable crop production. Consistent rainfall records are required to compute SPI. It is more likely that data sets would only have 90% or even 85% complete records. Many users of SPI do not have this luxury and may have to settle for less (75-85% complete data sets) unless they look for estimation techniques to fill in the gaps in the record. Long and pristine data records are neither practical nor typical in many cases, so the user needs to be aware of the statistical limitations of extreme events when dealing with shorter periods of records for various locations (Walsh, 1999; Guttman, 1998, 1999). At the end, users must make subjective decisions as to what tolerance of missing data they are willing to incorporate into the SPI calculations and analyses. Depending on the confidence and method of calculation, the use of estimated data is acceptable. Naturally, the fewer estimated data used the more reliable the results (World Meteorological Organisation, 2012).

The SPI was designed to quantify the precipitation deficit for multiple timescales. These timescales reflect the impact of drought on the availability of the different water resources. Soil moisture conditions respond to precipitation anomalies on a relatively short scale. Groundwater, stream flow and reservoir storage reflect the longer-term precipitation anomalies. McKee et al., (1993) originally calculated the SPI for 3-, 6-, 12-, 24- and 48-month timescales. The SPI calculation for any location is based on the long-term precipitation record for a desired period (McKee et al., 1995). Positive SPI values indicate greater than median precipitation and negative values indicate less than median precipitation. Since the SPI is normalized, wetter and drier climates can be represented in the same way.

A 1-month SPI map is very similar to a map displaying the percentage of normal precipitation for a 30-day period (McKee et al., 1993). In fact, the derived SPI is a more accurate representation of monthly precipitation because the distribution has been normalized. For example, a 1-month SPI at the end of November compares the 1-month precipitation total for November in that year with the November precipitation totals of all the years on record. Since the 1-month SPI reflects short-term conditions, its application can be related closely to meteorological types of drought along with short-term soil moisture and crop stress, especially during the growing season. The 1-month SPI may approximate conditions represented by the Crop Moisture Index (CPI), which is part of the PDSI suite of indices. Interpretation of the 1-month SPI may be misleading unless climatology is understood (McKee et al., 1995). In regions where rainfall is normally low during a month, large negative or positive SPIs may result even though the departure from the mean is relatively small. The 1-month SPI can also be misleading with precipitation values less than the normal in regions with a small normal precipitation total for a month. As with a percent of normal precipitation map, useful information is contained in the 1-month SPI maps, but caution must be observed when analysing them (World Meteorological Organisation, 2012).

The 3-month SPI provides a comparison of the precipitation over a specific 3-month period with the precipitation totals from the same 3-month period for all the years included in the historical record. In other words, a 3-month SPI at the end of February compares the December–January–February precipitation total in that year with the December–February precipitation totals of all the years on record for that location. Each year data is added, another year is added to the period of record, and thus the values from all years are used again. The values can and will change as the current year is compared historically and statistically to all prior years in the record of observation (McKee et al., 1993). A 3-month SPI reflects short- and medium-term moisture conditions and provides a seasonal estimation of precipitation. In primary agricultural regions, a 3-month SPI might be more effective in highlighting available moisture conditions than the slow-responding Palmer Index or other currently available hydrological indices (Bordi et al., 2001). A 3-month SPI at the end of June in tropical savannahs would capture precipitation trends during the important reproductive and early grain filling stages for both corn and soybeans. Meanwhile, the 3-month SPI at the end of

May gives an indication of soil moisture conditions as the growing season begins. It is important to compare the 3-month SPI with longer timescales (Kumar et al., 2009).

A relatively normal or even a wet 3-month period could occur in the middle of a longer-term drought that would only be visible over a long period. Looking at longer timescales can prevent misinterpretation believing that a drought might be over when in fact it is just a temporary wet period. Continuous and persistent drought monitoring is essential to determine when droughts begin and end (Lu, 2011). This helps avoid false alarms when going into and coming out of drought. Having a set of triggers in place, which are tied to actions within a drought plan, can help ensure this. As with the 1-month SPI, the 3-month SPI may be misleading in regions where it is normally dry during any given 3-month period. Large negative or positive SPIs may be associated with precipitation totals not very different from the mean (McKee et al., 1993; McKee et al., 1995; World Meteorological Organisation, 2012).

The 6-month SPI compares the precipitation for that period with the same 6-month period over the historical record. For example, a 6-month SPI at the end of September compares the precipitation total for the April–September period with all the past totals for that same period. The 6-month SPI indicates seasonal to medium-term trends in precipitation and is still considered to be more sensitive to conditions at this scale than the Palmer Index. A 6-month SPI can be very effective in showing the precipitation over distinct seasons. For example, a 6-month SPI at the end of March would give a very good indication of the amount of precipitation that has fallen during the very important wet season period from October through March. Information from a 6-month SPI may also begin to be associated with abnormal stream flows and reservoir levels, depending on the region and time of year (World Meteorological Organisation, 2012).

The 9-month SPI provides an indication of inter-seasonal precipitation patterns over medium timescale duration. Droughts usually take a season or more to develop. SPI values below -1.5 for these timescales are usually a good indication that dryness is having a significant impact on agriculture and may be affecting other sectors as well. Some regions may find that the pattern displayed by the map of the Palmer Index is closely related the 9-month SPI maps. For other areas, the Palmer Index is more closely related to the 12-month SPI. This period begins to bridge a short-term seasonal drought to those longer-term droughts that may become hydrological, or multi-year, in nature (World Meteorological Organisation, 2012).

The SPI at these timescales reflects long-term precipitation patterns. A 12-month SPI is a comparison of the precipitation for 12 consecutive months with that recorded in the same 12 consecutive months in all previous years of available data. Since these timescales are the cumulative result of shorter periods that may be above or below normal, the longer SPIs tend to gravitate toward zero unless a distinctive wet or dry trend is taking place. SPIs of these timescales are usually tied to stream flow and groundwater levels at longer timescales. In some locations, the 12-month SPI is most closely related with the Palmer Index and the two indices can reflect similar conditions (World Meteorological Organization, 2012).

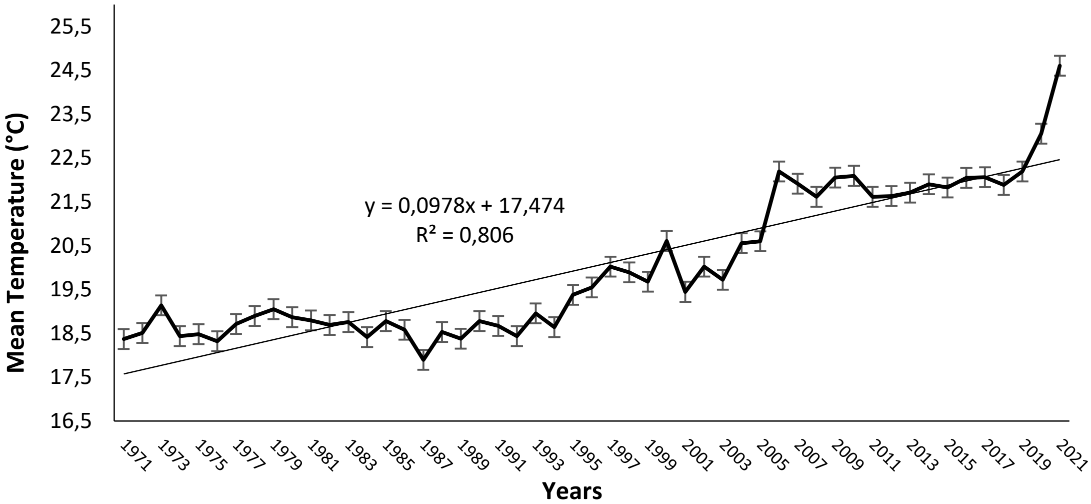
The strengths and weaknesses of the SPI can be summarized as follows:

- It is flexible and can be computed for multiple timescales
- Shorter timescale SPIs, for example 1-, 2- or 3-month SPIs, can provide early warning of drought and help assess drought severity
- It is spatially consistent, and it allows for comparisons between different locations in different climates
- Its probabilistic nature gives it historical context, which is well suited for planning and decision-making.

The weaknesses include the fact that it is based only on precipitation. SPI has no soil water-balance component, and thus no ratios of evapotranspiration/potential evapotranspiration (ET/PET) can be estimated. A new variation of the index attempts to address the PET issue by including a temperature component in the calculation of their new index called the Standardized Precipitation and Evapotranspiration Index (SPEI). The inputs required for SPEI are precipitation, mean temperature and latitude of site(s).

1.4.6 Inter-annual temperature variability

Temperatures have been increasing in Bamenda as perceived by the population of Bamenda II Sub-division. Available data shows an astronomical increase in the inter-annual temperature from 1971 to 2021 (Figure 1.16).

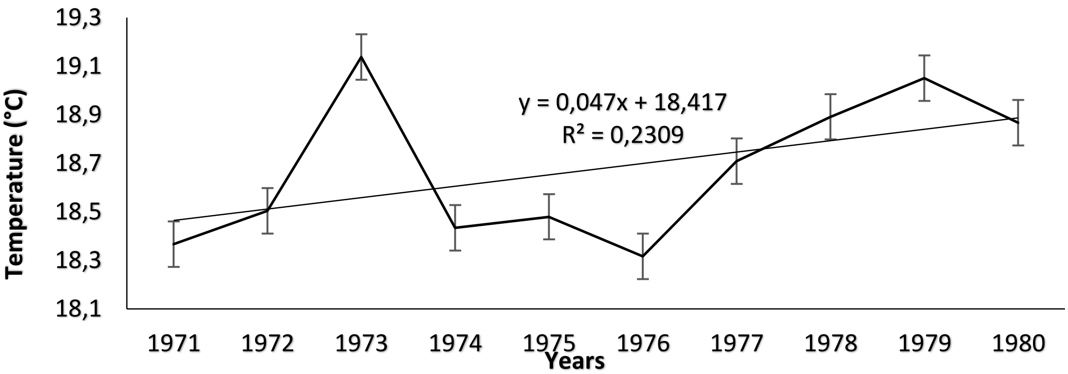


Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 16: Regional Meteorological Service for the North West (2021)

1.4.7 Decadal temperature trends

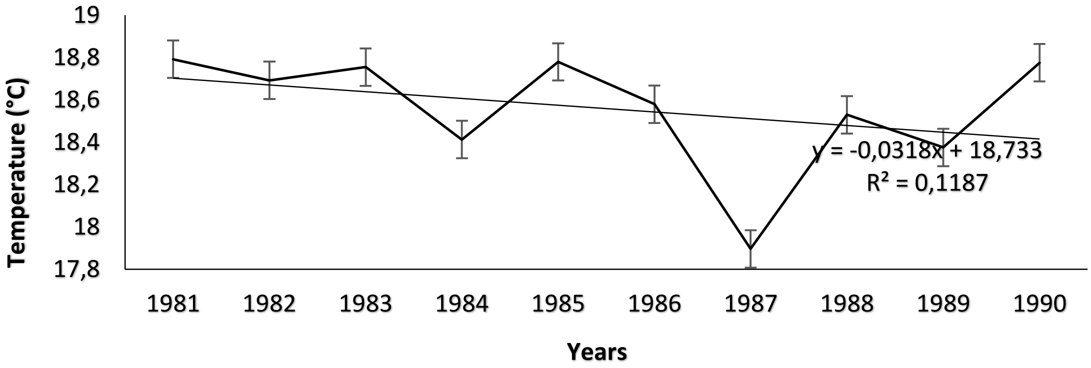
The decade 1971 to 1980 was characterized by increasing temperature, slightly decreasing temperature from 1981 to 1990, increasing from 1991 to 2000, increasing from 2001 to 2010 and increasing from 2011 to 2021 (Figure 1.17 to 1.23).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 17: Temperature trend for Bamenda (1971-1980)

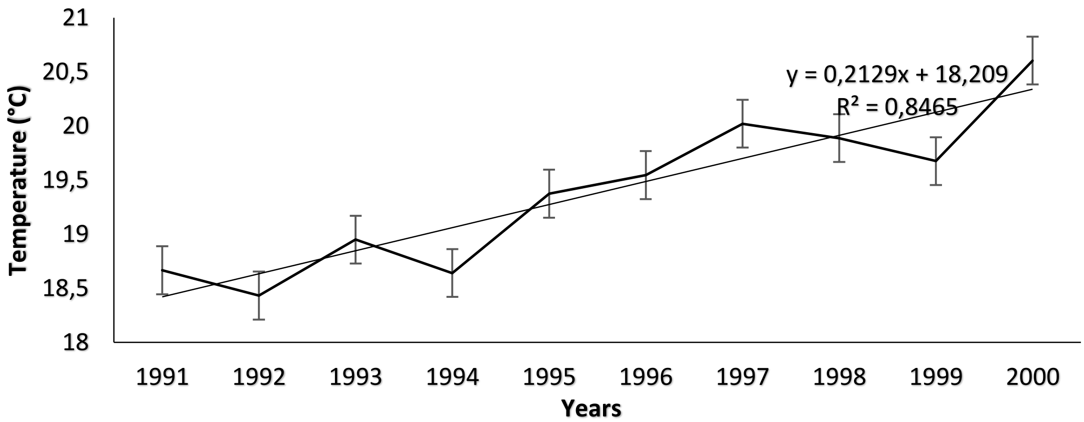
There was in increasing temperature trend from 1971-1980, with the peak records in 1973 (19.2^{o}C) and 1979 (18.6^{o}C). Exceptionally, the temperature slightly decreased from 1981-1990 (Figure 1.18).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 18: Temperature trend for Bamenda (1981-1990)

The lowest temperature during this decade was recorded in 1987 (17.85^{o}C). This might be an error in data recording because the data for this study is based on ground observations and manual recording of meteorological data. From 1991 to 2000, mean temperature has been increasing (Figure 1.19).



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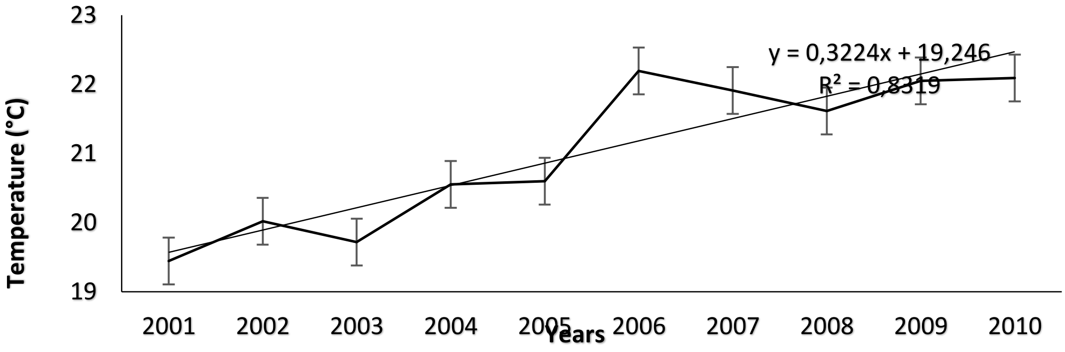
Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 19: Temperature trend for Bamenda (1991-2000)

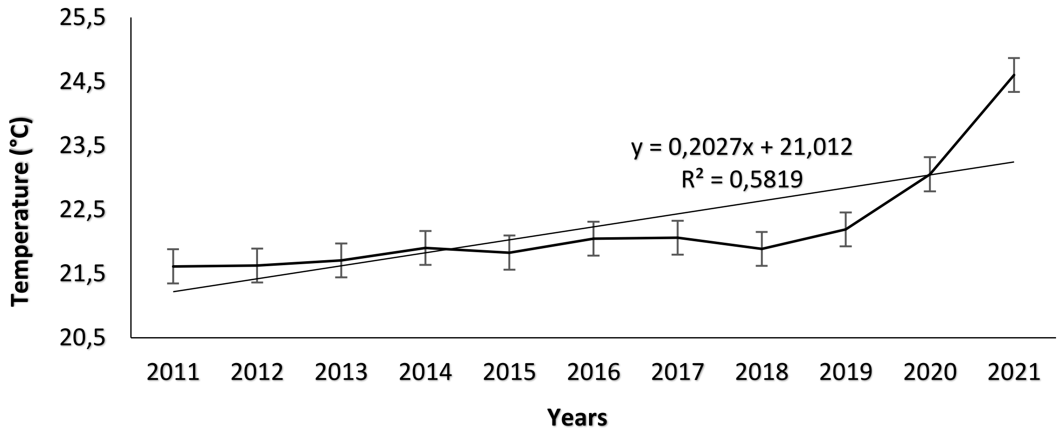
The temperature ranged from 18.54^{o}C to 20.54^{o}C. In the same vein, temperature has been increasing from 2001 to 2010 (Figure 1.20).



Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 20: Temperature trend for Bamenda (2001-2010)

This is in line with the general trend in global and local temperatures. From 2011 to 2021, local mean temperatures in Bamenda have plummeted (Figure 1.21) from 21.52^{o}C to over 24.5^{o}C.



Data source: Regional Meteorological Service for the North West (2021)

: Temperature trend for Bamenda (2011-2021)

Figure 1. 21: Temperature trend for Bamenda (2011-2021)

These rising temperatures have been accelerated by local Greenhouse Gas emissions from agriculture, grazing, deforestation, poor waste management, urbanization, amongst others. The temperature trends in Bamenda can be summarized thus (Table 1.7, Figure 1.21).

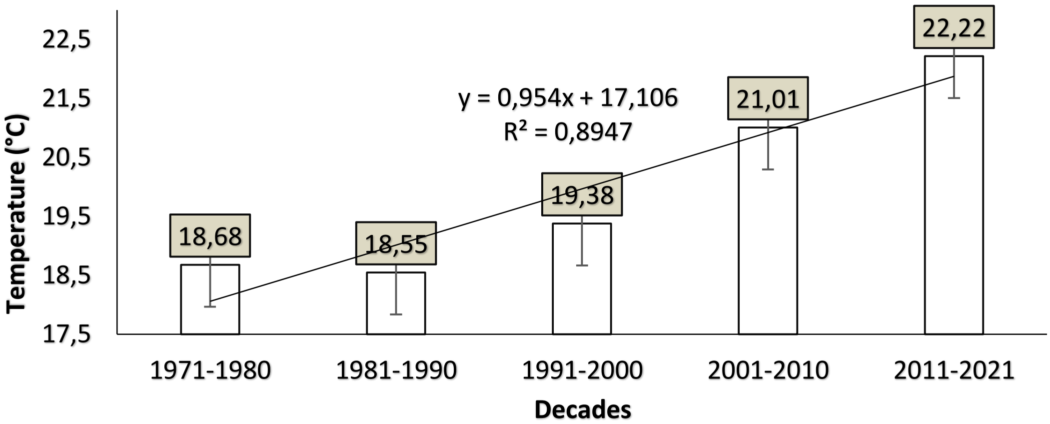
Table 1.7: Summary of temperature trends in Bamenda

Period	**Mean temperature (^{o}C)**	**Coefficient of Determination (R^2)**	**Temperature trend**
1971-1980	18.68	0.2309	Increasing

1981-1990	18.55	0.1187	Decreasing
1991-2000	19.38	0.8465	Increasing
2001-2010	21.01	0.8319	Increasing
2011-2021	22.22	0.5819	Increasing

Source: Figures 1.19 to 1.23

The increasing temperature trend in Bamenda has been consistent since 1991. Between 1971 and 2021, the mean temperature has increased by 3.54^{o}C, much higher than the global mean of (1-3^{o}C) 1990 levels as predicted by the Inter-governmental Panel on Climate Change-IPCC (2013).



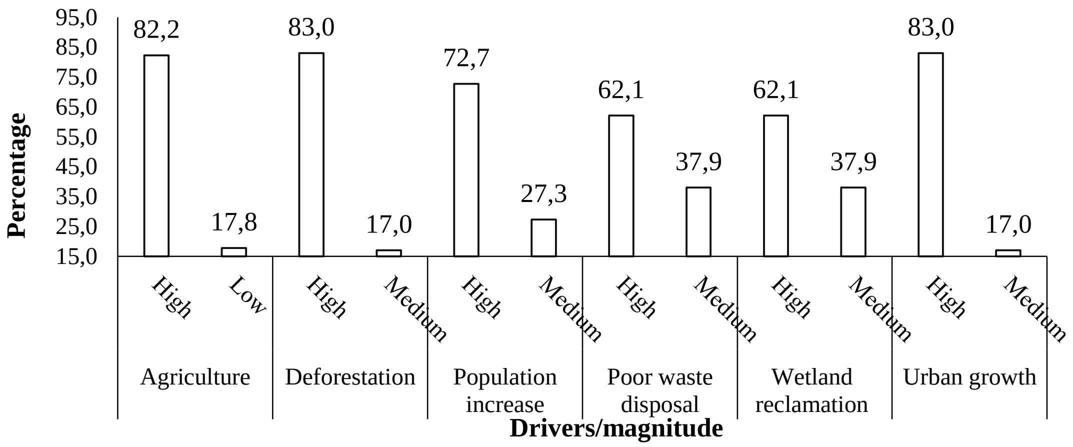
Data source: Regional Meteorological Service for the North West (2021)

Figure 1. 22: Decadal average temperature trend for Bamenda (1971-2021)

Rising temperatures against a backdrop dropping rainfall has negative impacts on crop production systems and other sources of livelihoods.

1.5 Drivers of climate variability

According to Aichele (2018), climate variability and change is mainly driven by human activities. The author stated that the concentration of greenhouse gasses including Carbon dioxide (CO_2) and methane (CH_4) has been steadily rising since the beginning of the Industrial Revolution (Etheridge et al., 2010). Anthropogenic carbon dioxide emissions from the combustion of fossil fuels have been the main contributor of rising carbon dioxide concentration levels in the atmosphere followed by carbon dioxide emissions from land use, land use change and forestry (Figure 1.23).



Source: Fieldwork, May 2022

Figure 1. 23:Population perception on drivers of climate variability in Bamenda II

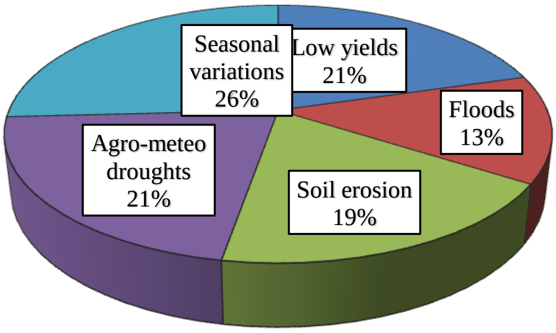
The main drivers of climate variability captured in this study are agriculture (high-82.2%), deforestation (high-83%), population increase (72.7%), poor waste disposal (high-62.1%), wetland reclamation (high-62.1%) and urban growth (high-83%).

Man is often considered as a constructive and destructive agent to the environment. The growing need for man to satisfy his wants has caused some modifications in the environment that is even accelerating climate change. These unsustainable human activities include poor farming techniques, population growth, urbanization, and poor waste management. The various effects of climate change to the environment includes flooding, droughts, weather related hazards.

According to the population perception, the drivers of climate variability in Bamenda II are mainly human factors. These human activities cause modifications on the natural environment and accelerate or cause climate variability. For example, deforestation due to population pressure, urban growth, population increase and agriculture exposes the natural environment to gasses that causes climate variability.

1.6 Effects of climate variability on agriculture

Famers know all too well that agriculture is highly dependent on weather. Modern methods, techniques and technologies has made today’s agriculture increasingly productive but agricultural success still depends on getting the right amount of rain and just the right amount of heat at just the right time of the year. Agriculture in Bamenda II Sub-division largely depends on rain fed agriculture and climate change has negatively affected crop cultivation through rising temperatures, increased temperature variability, changes in frequency and of dry spells and droughts and increasing intensity of extreme weather events which have reduced crop output (Figure 1.24).

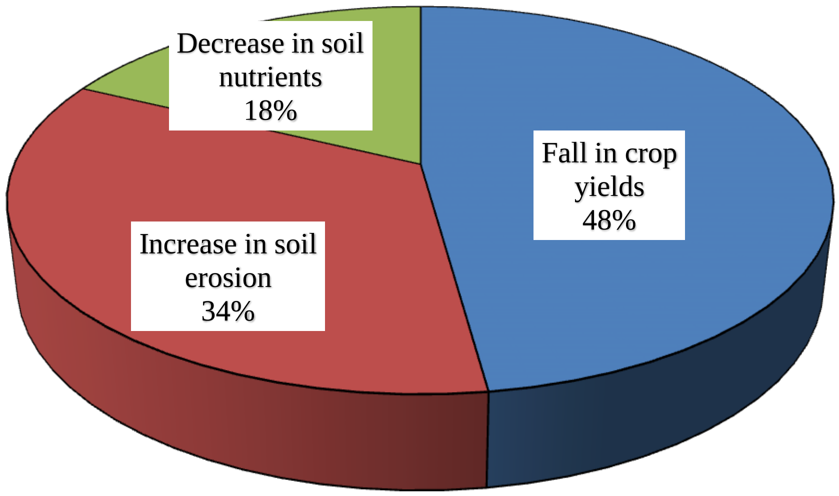


Source: Fieldwork, May 2022

Figure 1. 24: Effects of climate variability in Bamenda II

Field evidence revels that the main effect of climate variability on agriculture is seasonal variations (26%), recurrent ago-meteorological droughts (21%), low yields (21%), soil erosion (19%) and floods (13%). Globally, climate variability is a serious environmental threat that adversely affects agricultural productivity. The effect of climate variability on crop yield has affected mainly the population of developing countries of the world as they largely depend on agriculture. In Cameroon, agriculture is an important aspect of the economy. Crops and livestock contribute about 75% of Cameroon's GDP. Agricultural activity like crop cultivation is highly dependent on the climate (Etheridge et al., 2010).

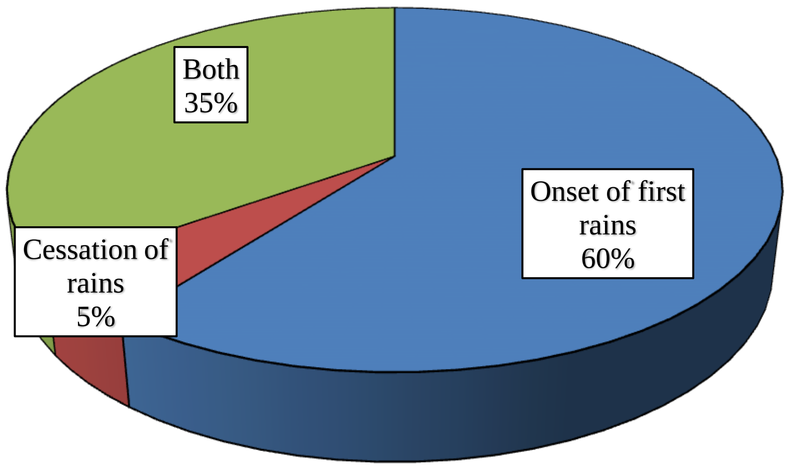
Climate variability could make it more difficult to grow crops and raise animals. However, when one moves from a global to a local (for example national or regional) focus, the impacts of climate variability on agricultural output becomes more complex (Costa-Roberts, 2011). While climate anomalies are expected to have spatially heterogeneous impacts on agriculture, yielding a net negative effect at the global level, their impacts at a local scale are less straightforward and they are expected to vary across space and time. Climate variability therefore affects agriculture by causing a fall in crops yields, decrease in soil nutrients and an increase rate of soil erosion (1.25).



Source: Fieldwork, May 2022

Figure 1. 25: Agricultural effects of climate variability on agriculture in Bamenda II

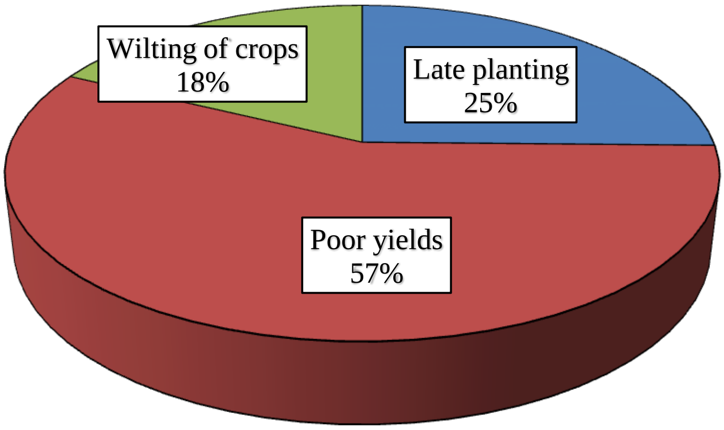
The main effect of climate variability on agriculture is causing a fall in crop yields (48%). The fall in crop yield is caused or accelerated by the increase soil erosion (34%) and decrease in soil nutrients (18%). Climate variability affects crop yields by causing cessation of rains and onset of first rains (Figure 1.26).



Source: Fieldwork, May 2022

Figure 1. 26: Effects of climate variability on crop yields in Bamenda II

The onset of first rains (60%) is the main way climate variability affects crop yields. Sometimes climate variability leads to cessation of rain after onset thereby confusing farmers on the planting season. After the planting of crops, there is an often long period of little or no rainfall which causes wilting of crops, late planting and this result to poor crops yields. Not only the impacts of climate on food production may vary across space, but countries' adaptive capacity to weather shocks is unlikely to be spatially homogeneous and rather differs across locations and strata of the populations within the same country (Alam, 2017). One key aspect that can restrain a country's resilience to climate variability is represented by the spatial distribution of food; the negative impacts of climate variability are likely to increase relative differences in food access and supply at both the global and local levels, as the degree of climate variation and the extent of its impacts on populations will differ from one community to another, and between rural and urban areas (Wheeler and von Braun, 2013) (Figure 1.27).



Source: Fieldwork, May 2022

Figure 1. 27: Effects of climate variability on maize production

Results revealed that the three main indicators of the climate effect on maize production in Bamenda II are poor yields (57%), late planting (25%) as result of inconsistencies in the onset of the growing season and wilting of crop (18%), barely a few weeks after germination. The distribution of lower and more rainfall results in extreme weather events that always pose serious changes in agricultural output. This, therefore, shows that the main climatic factors affecting crop yield in Bamenda II Sub-division is mainly rainfall and temperature.

1.7 Statistical Evaluation of rainfall and temperature variations in Bamenda II

The hypothesis that guided this chapter is that unusual and unsystematic climatic occurrences have led to significant variability in rainfall and temperature trends in Bamenda II. The analysis of variance (ANOVA) was used in verifying this hypothesis (Table 1.8).

Table 1.8: One-Way ANOVA for rainfall and temperature variability

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
Rainfall variability	Between Groups	26.760	2	13.380	8.026	.000
	Within Groups	416.750	250	1.667		
	Total	443.510	252			
Temperature variability	Between Groups	7.701	2	3.850	6.255	.002
	Within Groups	153.888	250	.616		
	Total	161.589	252			

The interactive frequency of rainfall variability is 8.026 with 2 and 250 degree of freedom (df) in which p-value is 0 while the interactive frequency for temperature variability is 6.255 in which p-value is 0.002. Since the p-value for rainfall variability and temperature variability are less than the standard p-value of 0.5 (rule of thumb), we therefore reject the hypothesis.

1.8 Conclusion

The population of Bamenda II Sub-division perceives that the magnitude of climate variability is high (46.2%). The dependable sources of climate information are radio and television with values of 41.5% and 33.3% respectively. Recent changes in climatic dynamics include increasing temperatures, oscillations in the onset of the first rains and cessation of the wet season, increasing incidence of wind on agriculture, human settlements and urban infrastructure. Meteorological data indicates that the inter-annual rainfall trend is decreasing, while the inter-annual temperature is increasing. Again, the trend of the growing season has been evaluated using the Cumulative Departure Index (CDI), showing a decreasing trend. Rainfall reliability (Coefficient of Variation-CV) shows that the trend has increased from 10.69% in the decade 1963-1972 (reliable) to 25.91% during the period 2013-2021 (unreliable). The CV is complemented by the Standardized Precipitation Index (SPI), which shows a decreasing trend with recurrent meteorological, hydrological and agricultural droughts. These culminate with a decreasing number of rainy days.

CHAPTER TWO

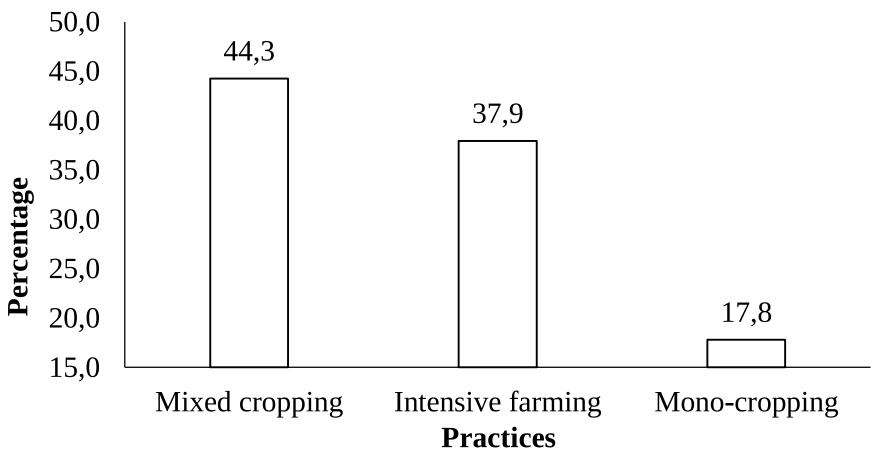
ASSESSMENT OF MAIZE PRODUCTION AND URBAN FOOD SECURITY IN BAMENDA II

2.0 Introduction

This chapter focuses on the impacts of climate variability on maize production and urban food security in Bamenda II. It is guided by the hypothesis that variation in rainfall and temperature does not significantly affect maize production. The chapter opens with a general assessment of agricultural practices in Bamenda II. It is supplemented by an assessment of food availability at the community level, dimensions of food security, perceived and actual changes in maize production to guarantee food security and maize consumption patterns and habits. Food security is assessed by the Household Food Insecurity Scale (HFIAS), which assesses food accessibility at the household level, household daily feeding pattern, adjustments to food shortages and wraps up with average income spent on food purchases.

2.1 Agricultural practices in Bamenda II

Agricultural productivity is measured as the ratio of agricultural outputs to agricultural inputs. While individual products are usually measured by weight, their varying densities make measuring overall agricultural output difficult. One of the ways farmers in Bamenda II adapt to maize production in order to meet food security in Bamenda is through mixed cropping, intensive farming and mono-cropping (Figure 2.1).



Source: Fieldwork, May 2022

Figure 2. 1: Agricultural practices in Bamenda II

The main type of agricultural practice in Bamenda II especially in maize production is mixed farming (44.3%). Mixed cropping is the cultivation of more than one type of crop on a particular piece of land and at a particular time. This often involves the planting of maize, beans and Irish potatoes in Bamenda II. Due to the continuous soil infertility, maize cultivation is done intensively (37.9%). This means applying more inputs like fertilizers and pesticides in farms. Mono-cropping which is the cultivation of a single crop on a particular farm is done at a lesser scale in Bamenda II Sub-division (17.8%).

2.2 Food availability at the community level

Food availability is relative, as it is determined by different indicators, such as income, family size, marital status and other factors. In this study, food availability at the community level as assesses by assessing if there is enough food, variation in food production, price fluctuations, rainfall reliability (climate variability and change), and the use of traditional techniques of land preparation like Ankara (Table 2.1).

The conceptualization of food security goals by Koc et al., (2014), however, goes beyond the adequacy of food quantity and quality and extends to the four ‘A’s (availability, accessibility, acceptability and adequacy). Availability connotes the physical presence (supply) of food in large amounts; accessibility addresses the demand for the food and suggests sufficient purchasing power or ability to acquire quality food at all time. Hence food should be accessible to all equally. Acceptability addresses foods cultural and symbolic value that the food available with respect to individuals’ cultural traditions. Adequacy is usually defined in terms of the long-term sustainability of food systems (FAO, 2008).

With a constant rise in food prices, and no corresponding increase in income, urban dwellers are obliged to record a high household dependency ratio (MINPAT, 2009). The situation is more challenging among the poor whose purchasing power has consistently been eroded by falling real wages, inflation and the rising cost of living despite attempts by the government to increase minimum wages. Urban dwellers and households are generally net food buyers who rely on their income for food security, spend a large proportion of household budget on food, and have little access to other safety nets like agriculture or land to ensure food access at all times (NIS, 2016).

Table 2.1: Food availability at the community level

Variables	Neighbourhoods	Yes		No	
		F	%	F	%
Enough food	Chomba	9	9.47	14	8.86
	Nsongwa	10	10.53	20	12.66
	Mbatu	22	23.16	40	25.32
	Mulang	44	46.32	61	38.61
	Ntankah	5	5.26	10	6.33
	Mukwebuh	5	5.26	13	8.23
Variation in food production	Chomba	9	10.11	14	8.54
	Nsongwa	12	13.48	18	10.98
	Mbatu	22	24.72	40	24.39
	Mulang	35	39.33	70	42.68
	Ntankah	6	6.74	9	5.49
	Mukwebuh	5	5.62	13	7.93
Price fluctuations	Chomba	14	8.54	9	10.11
	Nsongwa	18	10.98	12	13.48
	Mbatu	40	24.39	22	24.72
	Mulang	70	42.68	35	39.33
	Ntankah	9	5.49	6	6.74
	Mukwebuh	13	7.93	5	5.62
Rainfall reliability	Chomba	1	2.63	22	10.23
	Nsongwa	23	60.53	7	3.26
	Mbatu	2	5.26	60	27.91
	Mulang	4	10.53	101	46.98
	Ntankah	5	13.16	10	4.65
	Mukwebuh	3	7.89	15	6.98
Use of ankara	Chomba	12	22.22	11	5.53
	Nsongwa	0	0.00	30	15.08
	Mbatu	29	53.70	33	16.58
	Mulang	3	5.56	102	51.26
	Ntankah	9	16.67	6	3.02

	Mukwebuh	1	1.85	17	8.54

Source: Fieldwork, May 2022

Households in the urban areas were therefore generally deemed to be economically well-off, well-fed and more aware of nutritional issues. In response, households in Bamenda have developed resilience techniques to cope with the rising food prices, loss of farms and low income to survive within the urban and semi urban Bamenda.

2.3 Dimensions of food security

Satterthwaite et al., (2016) discussed the influences on food and farming of an increasingly urbanized world and a declining ratio of food producers to food consumers. The three fundamental components of food security, that is availability, access and utilization, differ in urban and rural contexts and across urban socio-economic groups. A greater diversity of both local and imported food products is available in cities although, most of the food is not produced within city boundaries. Similarly, much of the available food is processed either locally or imported in a processed form (FAO, 2014). To cater to busy urban lifestyles, cities offer access to a wide variety of food prepared outside the home, including street food and food served in restaurants and kiosks. Access to food in urban areas is dependent on cash exchange, with few exceptions, where urban food production contributes directly to the household intake. Dependence on purchased food is a leading factor in household food insecurity of poor urban populations who lack a fixed income. Although a wider variety of food is available, the food consumed in urban areas is not necessarily of superior nutritional quality and food safety is a growing concern in many urban environments (National Institute of Statistics-NIS, 2016). The situation is a reflection of Bamenda town which faces food insecurity mainly due to urban growth and urban connectivity crises. The various dimensions of food security in Bamenda II include availability, accessibility, utilization and stability (Table 2.2).

Table 2.2: Dimensions of food security

Dimensions	**Scales**	**Frequency**	**Percentage**
Availability	Increase	45	17.8
	Decrease	208	82.2

Accessibility	Increase	69	27.3
	Decrease	184	72.7
Utilization	Increase	120	47.4
	Decrease	133	52.6
Stability	Decrease	208	82.2
	No change	45	17.8

Source: Fieldwork, May 2022

The availability of food in Bamenda II is largely decreasing (82.2%). Urban connectivity crises in Bamenda II therefore limit the food supply into the municipality from other parts of the North West region. This explains why food accessibility (72.7%) and stability (82.2%) is also at a decrease.

2.4 Perceived and actual changes in maize yields

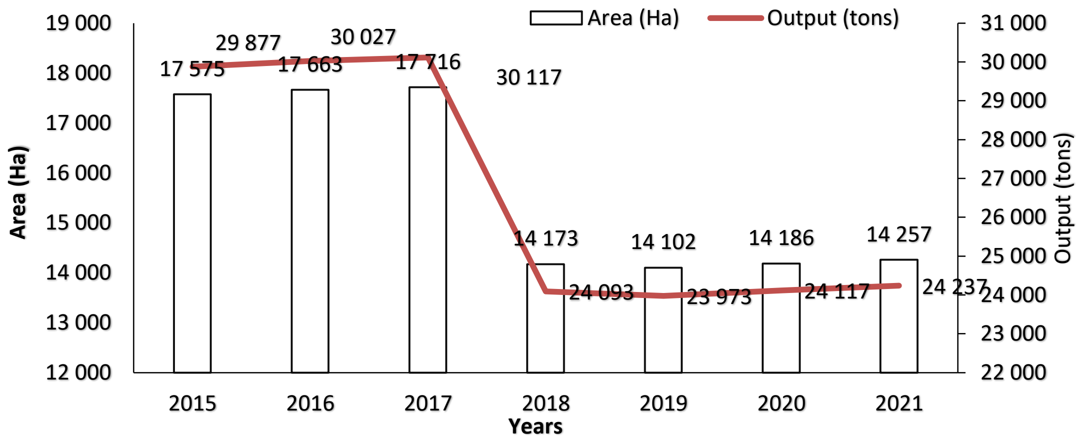
The various types of maize cultivated in Bamenda II include ATP, Panner, Coca and white maize (Table 2.3).

Table 2.3: Perceived and actual changes in maize yields

Varieties	Scales	Frequency	Percentage
ATP	Increase	96	37.9
	Decrease	133	52.6
	No change	24	9.5
PANNAR	Increase	52	20.6
	Decrease	156	61.7
	No change	45	17.8
Coca	Increase	52	20.6
	Decrease	177	70.0
	No change	24	9.5
White maize	Increase	97	38.3
	Decrease	156	61.7
Others	Increase	121	47.8
	Decrease	132	52.2

Source: Fieldwork, May 2022

The various maize varieties are largely decreasing in output in Mezam Division (Figure 2.2), as well as in Bamenda II (Figure 2.3).



Source: Regional Delegation for Agriculture and Rural Development, North West (2021)

Figure2. 2: Maize production trend in Mezam Division (2015-2021)

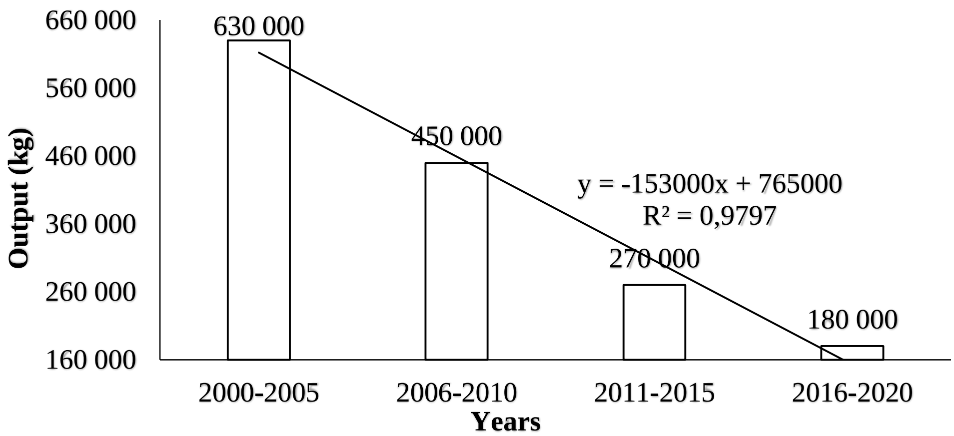


Figure2. 3: Maize output in Bamenda II Sub-division (2000-2020)

Data source: Divisional Delegation of Agriculture and Rural Development, Mezam

This is due to agricultural challenges such as climate variability and change, amongst other factors. Local white maize (2 bags of 100kg/ha), high yield variety white maize (10 bags of 100 kg/ha), high yield yellow corn (15 bags of 100 kg/ha).

It has been established in this study that climate variability (rainfall decline and rising temperatures) is responsible for a downward trend in crop production and maize in particular.

The little data on maize production has been correlated with rainfall and temperature data (Figure 2.4 and 2.5).

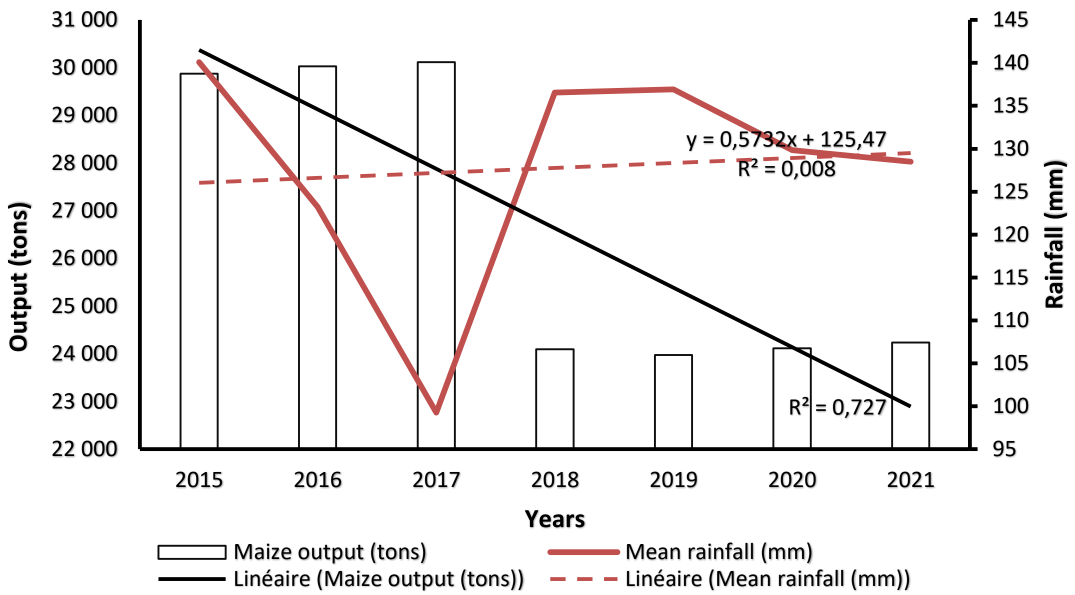


Figure2. 4: The relationship between rainfall and maize production in Bamenda II Sub-division

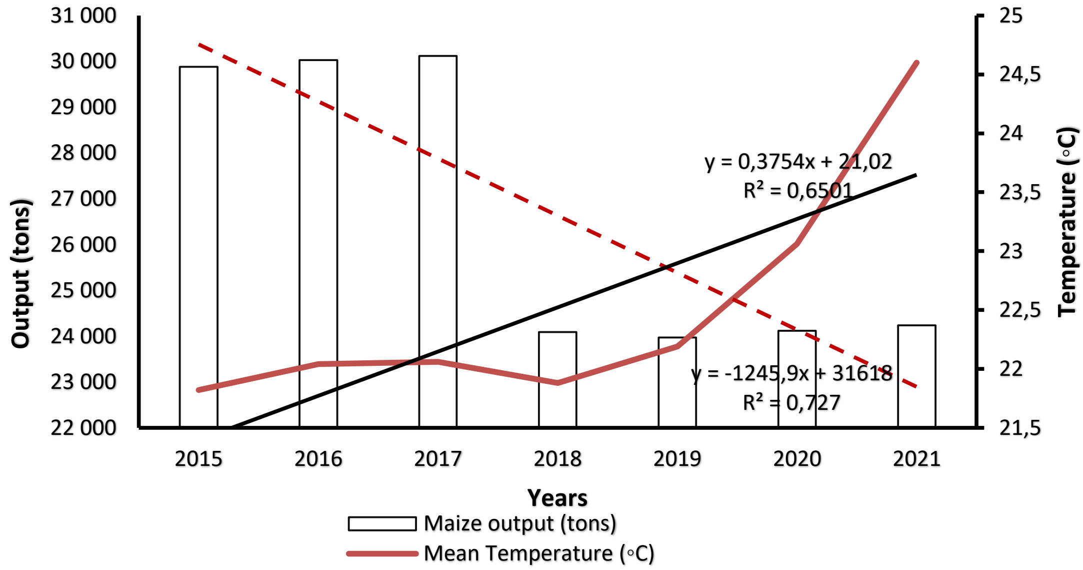


Figure2. 5: The relationship between temperature and maize production in Bamenda II Sub-division

Though mean annual rainfall from 2015-2021 showed signs of near stability and slight increase, the mean temperature has continued to increase during the same period. Maize production on the other hand has been decreasing. The drop in maize production cannot only be attributed to rainfall and temperature variations, but other production factors like farm inputs, agricultural credits to farmers and readiness of farmers to accept new learning production techniques.

The center of origin of maize is Mexico or Central America, with a possible secondary origin in South America (Martin et al., 1967; Wilkes, 1979; Pursglove, 1983). The scientific name of maize is Zea mays. Zea mays belong to the botanical family of Poaceae (Gramineae) which is divided into the two sub-families, the Panicoideae and the Poideae. The subfamily Panicoideae has three tribes including Maydeae which contains maize (Pursglove, 1983).

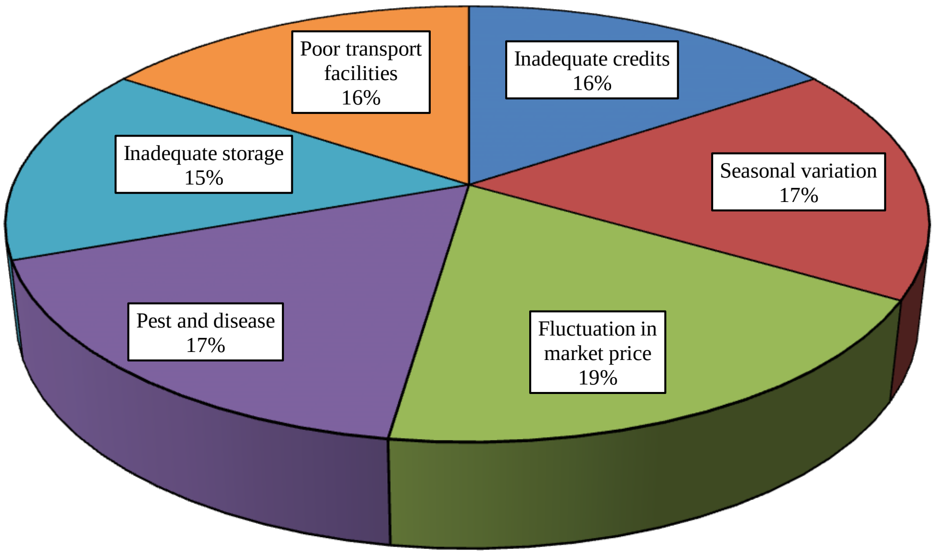
Martin et al., (1967) and Pursglove (1983) describe the ecology of maize. The crop is grown from latitudes 50ºN to 40ºS and from sea level to 3300m. It is grown in regions with isotherms at tasseling of 21 - 30ºC. Rainfall during the growing period should not fall below 200 mm and 450 - 600 mm are preferred, with periods of clear warm weather between the rain storms. Maize can be grown on a wide variety of soils, but performs best on well-drained well-aerated deep, warm loams and silt loams containing adequate organic matter and well supplied with available nutrients. The plant produces a large amount of biomass over a relatively short period; consequently, it needs abundant supply of nitrogen. The plant is perhaps the most completely domesticated of all field crops. Its perpetuation for centuries has depended wholly upon the care of man (Martin et al., 1967).

Maize (zea mays) is the staple crop in Cameroon. It is consumed mainly as a dry fermented dough (fufu), and in multiple other forms including corn beer (kwacha), which is produced and sold in huge quantities in villages and towns, forming an important contribution to the local economy and thus reduces hunger among the rural poor. Because of its multiple uses, maize provides the bases for financial profitability after the devaluation of the CFA franc in January 1994 (Adesina and Coulibaly, 1998; Ngoko et al., 2002).

2.5 Problems encountered in maize production

According to Bronhilda (2017), food security incorporates a measure of resilience to future disruption or unavailability of critical food supply due to various risk factors, some of which are uncontrolled and rapid urbanization, poor farm to market roads, loss of land for residential

175 purposes, traditional farming techniques and rapid changing food habits which characterize Bamenda II (Jonathan et al., 2014). Farmers are experiencing the need to adapt to climate variability and are developing different strategies. This study contributes to the understanding of farmer's adaptation choices, their determinants and their implementation. One of the widest spread anthropogenic challenges affecting agricultural production is climate variability. An adjustment to the actual or expected changes has to be therefore among priorities in policy decisions. Farmers behavioral change towards adaptation and willingness to take action are important as are policy decisions. The need for adaptation to ensure food security particularly is highly justified and supported at the political and policy levels. The various encountered in maize production in Bamenda II includes poor transport, inadequate credit, pest and diseases, seasonal variation, fluctuation in market prices for maize products and inadequate storage facilities (Figure 2.6).



Source: Fieldwork, May 2022

Figure2. 6: Problems encountered in maize production

The main problem encountered in maize production in Bamenda II is fluctuation in market prices (19%). The fluctuations range from farm inputs to the price of maize. A recurrent problem in maize farming is attack by stem borers (plate 2.1)

Plate 2. 1: Maize crop attacked by fall army worms and maize stem borers

This pest attacks the crop there is rainfall deficiency. Agricultural technicians indicated that the attack occurs when the maize crop is still tender, and the worms develop as the crop is growing.

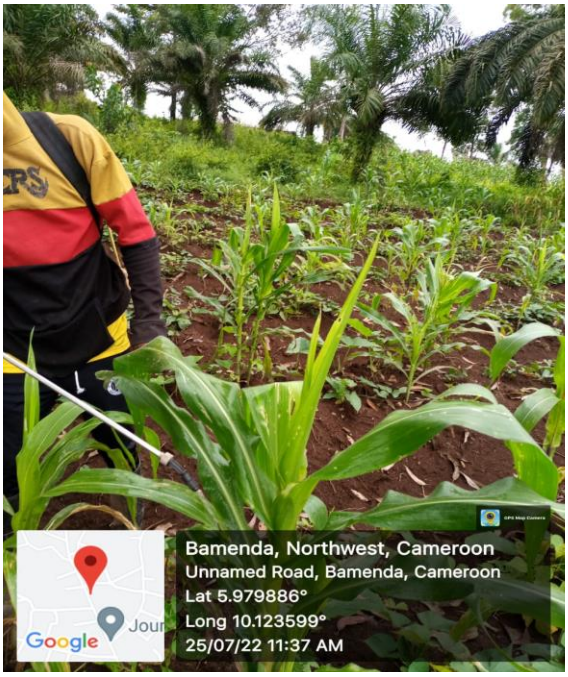
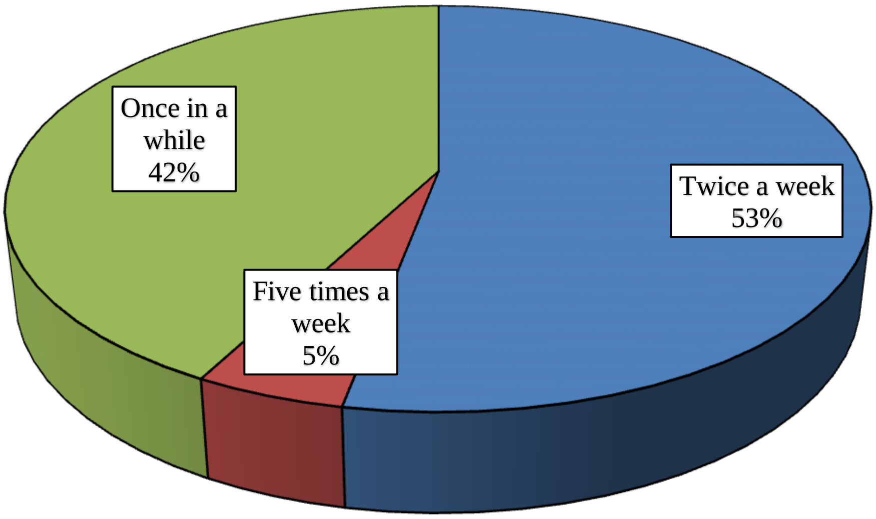


Photo 2. 1: the use of insecticides to overcome the effects of ,maize stem borer and fall army worm

2.6 Maize consumption

The sampled population had different ranges in maize consumption (Figure 2.7). A greater proportion of the sampled population (53%) consumes maize twice a week while the least proportion consumes maize five times a week (5%).



Source: Fieldwork, May 2022

Figure 2. 7: Maize consumption

The consumption pattern is determined by the traditional dish as some respondents have "fufu corn" as a traditional meal and will therefore consume more. Corn is used in Bamenda II for pap, fufu corn, and corn chaff amongst others (Figure 2.8).

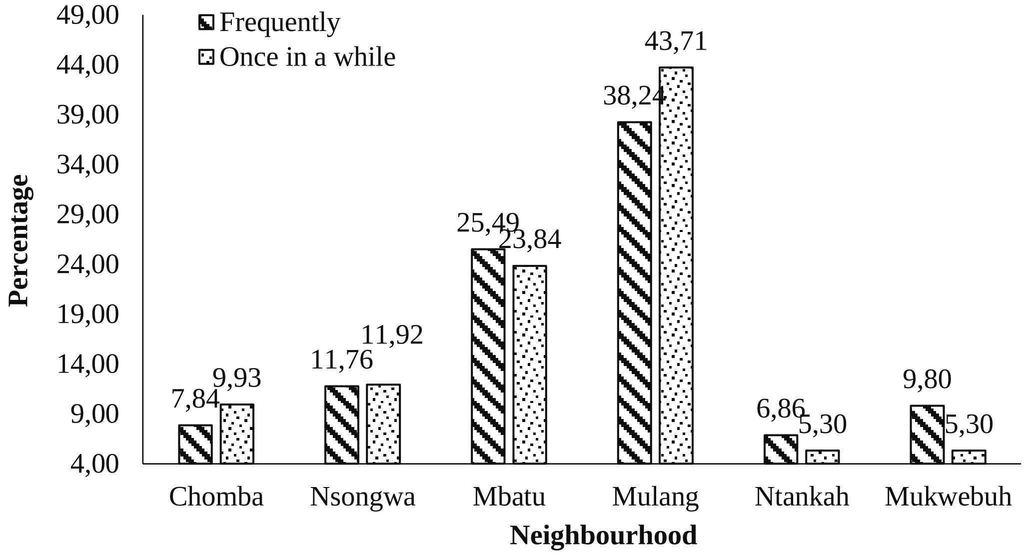
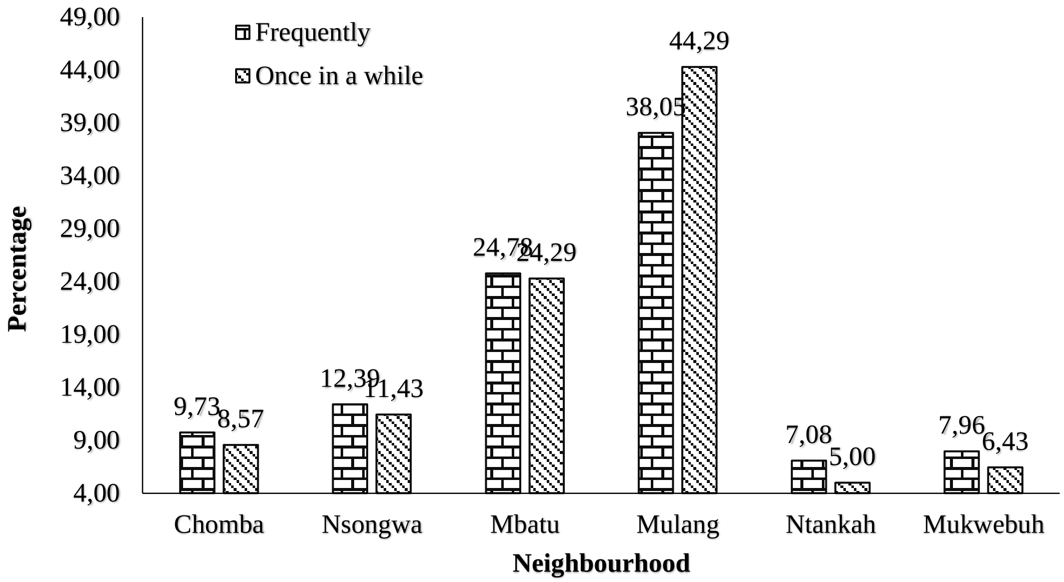


Figure2. 8: Consumption pattern of corn pap

Source: Fieldwork, May 2022

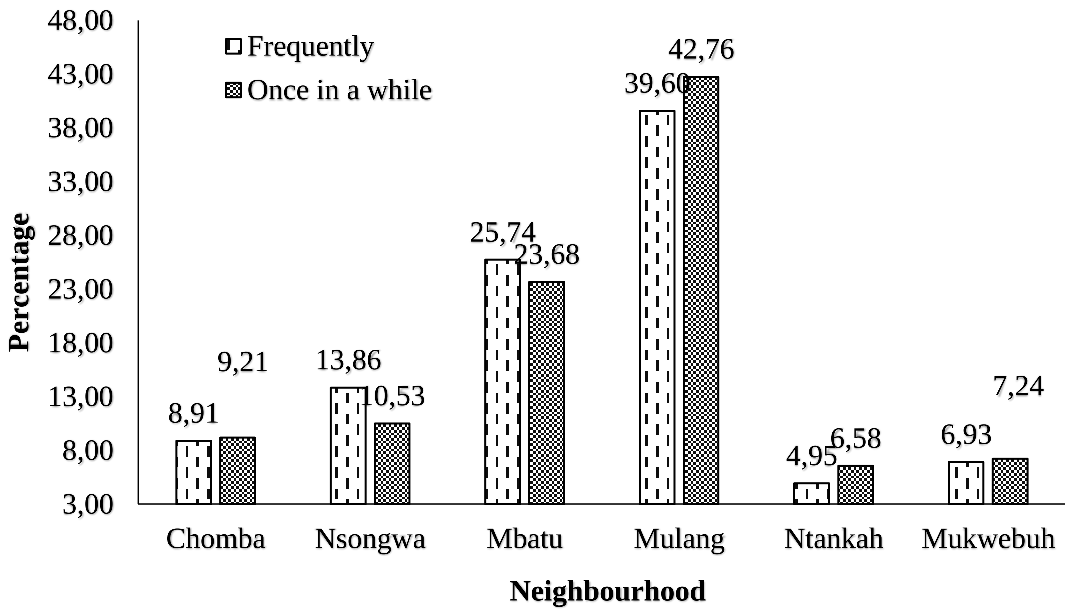
In Bamenda II, corn pap is highly consumed for pap in Mulang (38.24%) than other neighborhoods like Ntankah where pap is largely consumed once a while (5.3%). Fufu corn consumption also varies (Figure 2.9).



Source: Fieldwork, May 2022

Figure2. 9: Consumption pattern of fufu corn

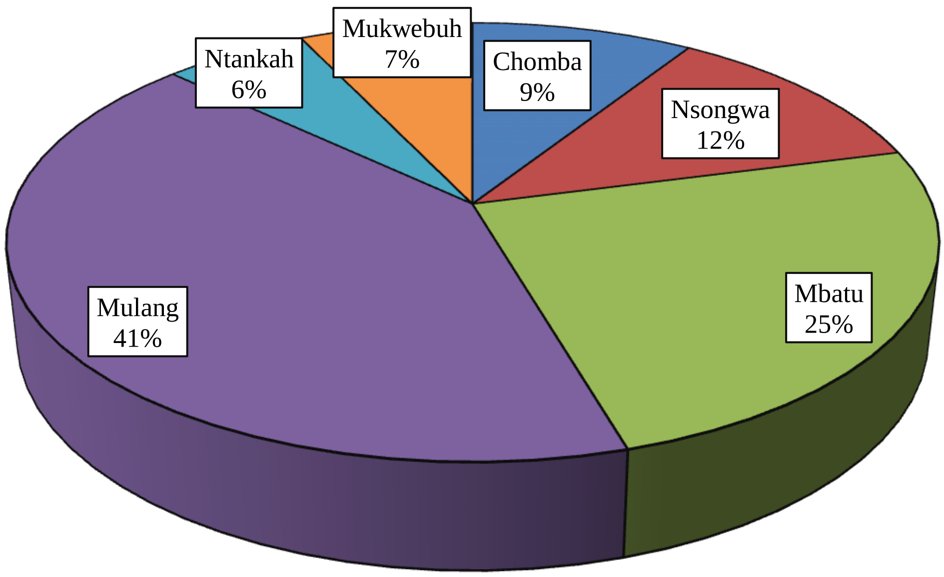
In Bamenda II, corn is highly consumed for fufu corn in Mulang (38.05%) than other neighborhoods like Ntankah where fufu corn is largely consumed once a while (5%). Corn chaff consumption also varies (Figure 2.10).



Source: Fieldwork, May 2022

Figure2. 10: Consumption pattern of corn chaff

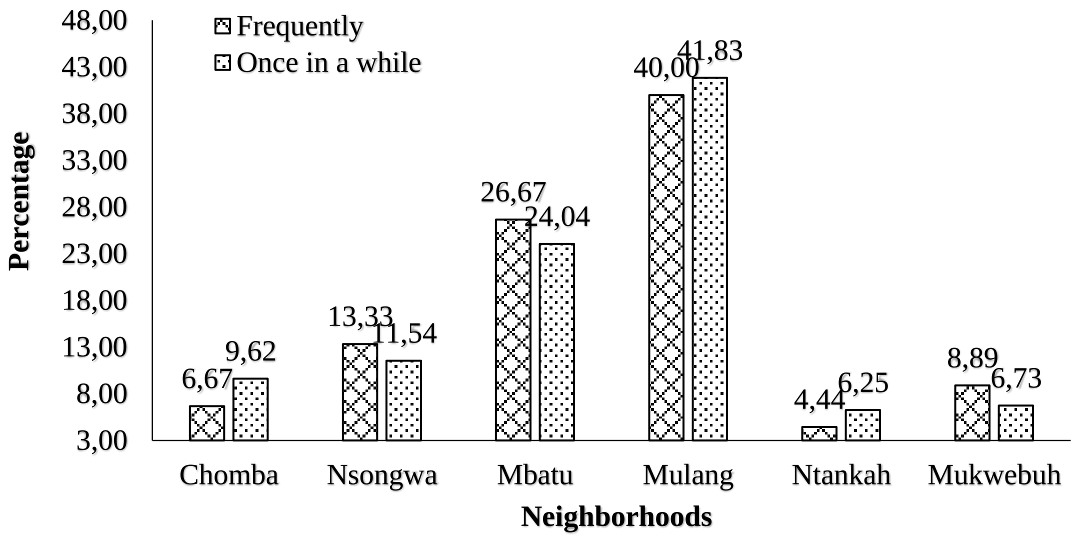
In Bamenda II, corn is highly consumed for corn chaff in Mulang (39.6%) than other neighborhoods like Ntankah where corn chaff is largely consumed once a while (4.95%). Boiled corn consumption also varies (Figure 2.11).



Source: Fieldwork, May 2022

Figure2. 11: Consumption pattern of boiled corn

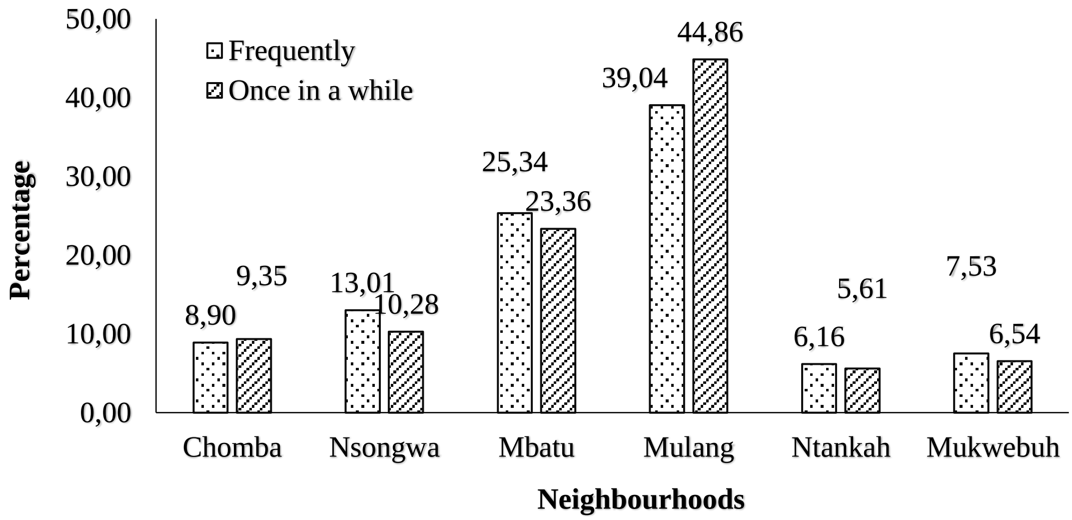
In Bamenda II, boiled corn is highly consumed in Mulang (41%) than other neighborhoods like Ntankah where pap is largely consumed once a while (6%). Fried corn consumption also varies (Figure 2.12).



Source: Fieldwork, May 2022

Figure2. 12: Consumption pattern of fried corn

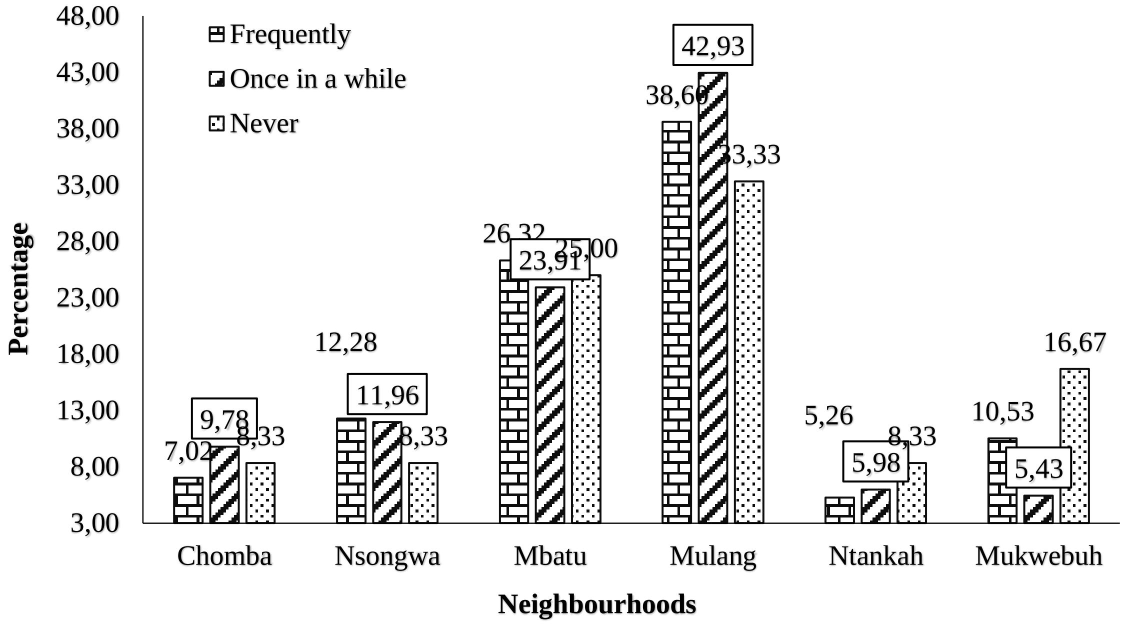
In Bamenda II, fried corn is highly consumed in Mulang (40%) than other neighborhoods like Ntankah where pap is largely consumed once a while (4.44%). Roasted corn consumption also varies as (Figure 2.13).



Source: Fieldwork, May 2022

Figure2. 13: Consumption pattern of roasted corn

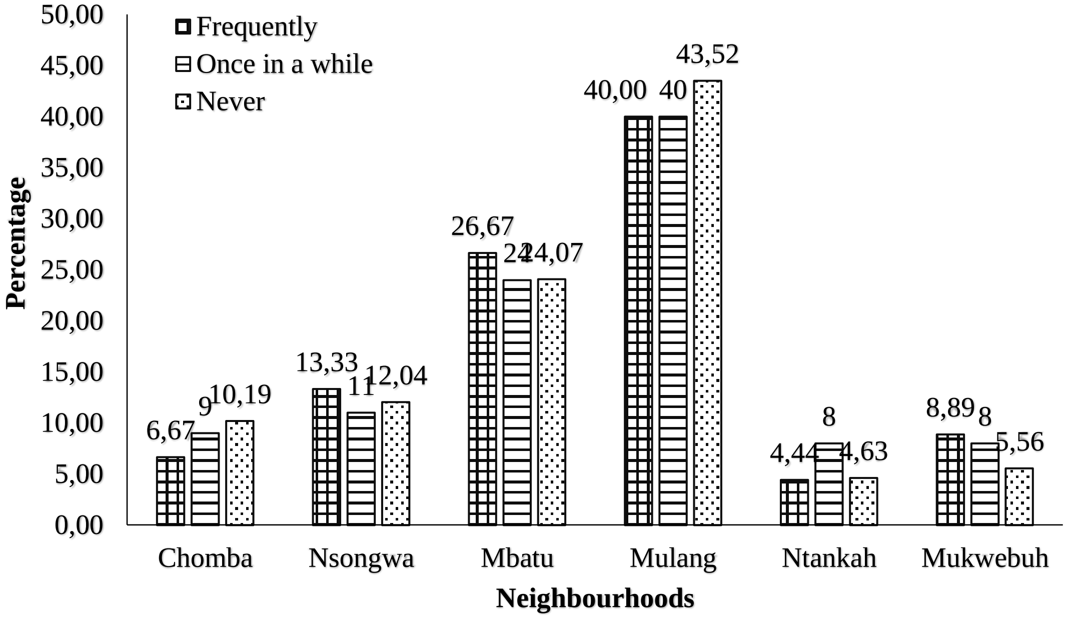
In Bamenda II, fried corn is highly consumed in Mulang (39.04%) than other neighborhoods like Ntankah where fried corn is largely consumed once a while (6.16%). In Bamenda II, koki corn is highly consumed in Mulang (38.6%) than other neighborhoods like Ntankah where pap is largely consumed once a while (5.98%). Koki corn consumption also varies (Figure 2.14).



Source: Fieldwork, May 2022

Figure2. 14: Consumption pattern of koki corn

In Bamenda II, corn drinks are highly consumed for pap in Mulang (40%) than other neighborhoods like Ntankah where pap is largely consumed once a while (8%) (Figure 2.15).



Source: Fieldwork, May 2022

Figure2. 15: Consumption pattern of corn drinks

2.7 Household Food Insecurity Assessment Scale (HFIAS)

Food security dimensions in Bamenda includes availability of food supply through urban connectivity, physical and economic access to food through urban connectivity, utilization safety and quality and stability availability, access and utilization. Most of the food sources produced by the farmers, livestock production, purchase, exchange of food for labour and food at place of work and school (for school-going children) (Table 2.4).

Table 2.4: Sources of food at the household level

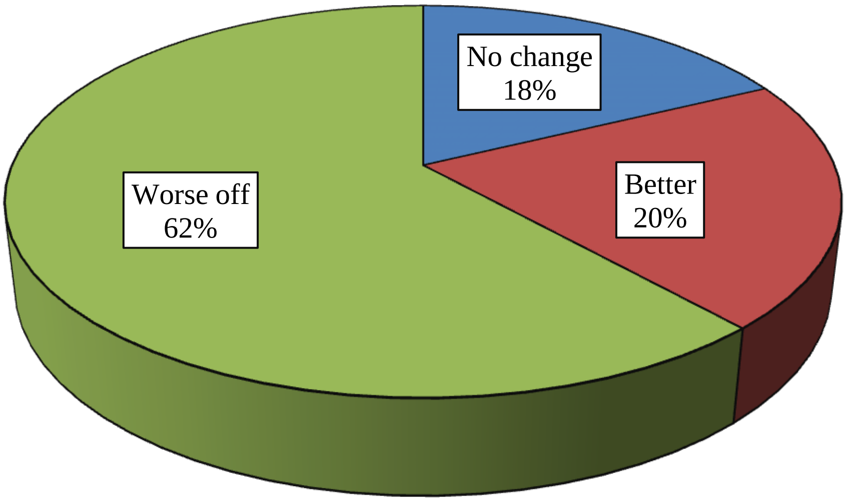
Sources	Yes		No		Not applicable	
	F	%	F	%	F	%
Own crop production	100	39.5	153	60.5	0	0
Barter	12	4.7	45	17.8	45	17.8
Own livestock products	152	60.1	89	35.2	12	4.7
Purchase	121	47.8	132	52.2	0	0
Wild food collection	210	83.0	0	0.0	43	17.0
Exchange labour for food	208	82.2	0	0.0	45	17.8
Hunting	44	17.4	209	82.6	0	0.0
Steal	0	0.0	12	4.7	241	95.26
Friends/relatives	95	37.5	158	62.5	0	0.0
Food at school	164	64.8	45	17.8	44	17.4
Food at work	95	37.5	114	45.1	44	17.4
Other food sources	95	37.5	45	17.8	113	44.7

Source: Fieldwork, May 2022

The connectivity of the town with the surrounding suburbs can therefore ensure food security in Bamenda II but this is however influenced by poor urban connectivity due to insecurity and poor state of farm to market roads. There is also concern and frustration on the dismal progress of domestic agriculture development which, in many ways, affects food security especially in the rural areas. It is precisely this state that the task of looking at the lens again, thinking through the past and emerging issues, revisiting the scope and approach in research, and digging deeper into the challenges in agriculture, food, nutrition, and environment must continue. There are persistent and new dynamics at play in the state of development in the country as well as in the region and the Bamenda II Municipality that warrant rounds of scientific investigation on food security.

2.8 Food accessibility at the household level as compared to five years ago

The level of food accessibility in Bamenda II as compared to five years ago was considered to better and worse off (Figure 2.16).



Source: Fieldwork, May 2022

Figure2. 16: Food accessibility at the household level as compared to five years ago

A greater proportion of the sampled population of Bamenda II considered food accessibility to be worse off (62%) as compared to five years. This is due to the factors influencing agriculture such as environmental challenges and the poor security situation.

2.9 The situation of food security at the household level

The situation of food security is however different at the household level. The situation of food security is influenced at the household level by factors such as income not increasing at the rate of inflation, poor harvest due to drought amongst others (Table 2.5).

The most widely accepted definition of food security, which was adopted at the 1996 World Food Summit, takes multiple dimensions of food security into account. It states that food security exists "when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life". The definition covers a range of issues that could hinder the attainment of food security; it encompasses not only insufficient quality and quantity of food intake, but also anxiety about food supply and access. Numerous conceptual and measurement problems have been identified with regard to measuring a complex, unobservable phenomenon such as food security. Despite this, many indicators have been developed over the years to assess food security because of its policy significance.

Table 2.5: The situation of food security at the household level

Variables	<5%	6-10%	11-15%	16-20%	21-25%	26%+

	F	%	F	%	F	%	F	%	F	%	F	%
Income not increasing at the rate of inflation	97	38.3	0	0	44	17.4	43	17.0	24	9.5	45	17.8
Poor harvest due to drought	95	37.5	89	35.2	12	4.7	0	0.0	45	17.8	12	4.7
Poor harvest due to low temperatures	139	54.9	0	0	45	17.8	57	22.5	0	0	12	4.7
Poor harvest due to pests and diseases	95	37.5	44	17.4	45	17.8	0	0	12	4.7	57	22.5
Lack of agricultural inputs	95	37.5	12	4.7	0	0.0	44	17.4	45	17.8	57	22.5
Poor salaries	95	37.5	0	0.0	56	22.1	0	0	0	0	102	40.3
Retirement	184	72.7	0	0.0	0.0	0.0	57	22.5	0	0.0	12	4.7
Retrenchment	95	37.5	134	53.0	0	0.0	0.0	0.0	12	4.7	12	4.7
Reduced government support	95	37.5	0	0.0	45	17.8	44	17.4	0	0	69	27.3
Increased household size	95	37.5	44	17.4	0	0	45	17.8	0	0	69	27.3
Death of the main food provider	95	37.5	44	17.4	0	0	45	17.8	45	17.8	24	9.5
Anglophone crisis	139	54.9	45	17.8	0	0	45	17.8	0	0.0	24	9.5
Average		43.4		13.57		8.1		12.5		6.0		16.3

F: Frequency. Source: Fieldwork, May 2022

Recent evidence on food security points to an increase in the number of undernourished people over the past few years, despite renewed global policy emphasis and consensus on the need to end hunger and poverty worldwide (Larson, 2017).

2.10 Daily feeding pattern at the household level

The daily feeding pattern at the household level varies and is always a herculean task (Table 2.6).Worried about household food inadequacy, inadequate food varieties, limited food due to lack of resources, eating unwanted foods, eating smaller meals, fewer meals due of lack of resources, eating any kind of food due to inadequate resources, going to bed hungry and going a whole day without food.

Table 2.6: Daily feeding pattern at the household level

Variables	Rarely		Sometimes		Often	
	F	%	F	%	F	%
Worried about household food inadequacy	45	17.8	139	54.9	69	27.3
Inadequate food varieties	0.0	0.0	140	55.3	113	44.7
Limited food due to lack of resources	0.0	0	253	100.0	0	0
Eating unwanted foods	0.0	0	208	82.2	45	17.8
Eating smaller meals	45	17.8	208	82.2	0	0.0
Fewer meals due of lack of resources	0	0	152	60.1	101	39.9
Eating any kind of food due to inadequate resources	198	78.3	43	17.0	12	4.7
Going to bed hungry	209	82.6	44	17.4	0	0.0
Going a whole day without food	253	100.0	0	0.0	0.0	0.0
Average		32.9		52.1		14.9

F: Frequency. Source: Fieldwork, May 2022

The factors have made the population top adopt strategies to adjust to food shortages.

2.11 Adjustments to food shortages

There has been little work on understanding food security at the urban scale, especially in the Indian context. This is the first study of urban food security at a city scale in India that focuses on self-reported measures of food access and food intake using experiential metrics (Popkin, 2012). Through the study, the prevalence of food security at a city scale based on self-reported experiences by households was analyzed and the relationship of food security with income and non-income factors that affect food security, such as educational attainment, access to infrastructure, household structure, housing type, migration status, and access to social safety nets (Table 2.7).

The food security dimensions in Bamenda II includes availability of food supply through urban connectivity, physical and economic access to food through urban connectivity, utilization safety and quality and stability availability, access and utilization. The connectivity of the town with the surrounding divisions and Sub-divisions can therefore ensure food security in Bamenda II but this is however influenced by poor urban connectivity due to insecurity and poor state of farm to market roads. There is also concern and frustration on the dismal progress of domestic agriculture development which, in many ways, affects food security especially in the rural areas.

Table 2.7: Adjustments to food shortages

Variables	SA		A		SD		D		N	
	F	%	F	%	F	%	F	%	F	%
Food grants	0.0	0.0	89	35.2	95	37.5	69	27.3	0	0.0
Borrow money from friends or relatives	0.0	0.0	45	17.8	208	82.2	0	0	0	0
Dispose household assets	0.0	0.0	45	17.8	208	82.2	0	0	0	0
Reduction in non-food household expenditure	89	35.2	69	27.3	95	37.5	0	0	0	0
Reduce the number of meals per day	89	35.2	69	27.3	95	37.5	0	0	0	0
Resort to external relationships to secure food	0.0	0.0	69	27.3	95	37.5	44	17.4	45	17.8
Change area of residence	0.0	0.0	0.0	0.0	196	77.5	12	4.7	45	17.8
Petty trading	140	55.3	101	39.9	12	4.7	0	0	0	0
Sale of livestock	88	34.8	96	37.9	69	27.3	0	0	0	0
Credit union loan	52	20.6	45	17.8	156	61.7	0	0	0	0
Reduce the amount of food	113	44.7	0	0	0	0	0	0	0	0

Did not pay credits already owed	0	0	0	0	140	55.3	0	0	0	0
Over-use of natural resources	45	17.8	0	0	120	47.4	0	0	88	34.8
Other adjustment mechanisms	140	55.3	0	0	69	27.3	0	0	44	17.4
Average		21.3		17.7		44.0		3.5		6.3

F: Frequency, SA: Strongly Agree, A: Agree, SD: Strongly Disagree, D: Disagree, N: Neutral

Source: Fieldwork, May 2022

It is precisely this state that the task of looking at the lens again, thinking through the past and emerging issues, revisiting the scope and approach in research, and digging deeper into the challenges in the Philippines agriculture, food, nutrition, and environment must continue. There are persistent and new dynamics at play in the state of development in the country as well as in the region that warrant rounds of scientific investigation.

2.12 Average income spent on food

The sampled population had different proportions of their monthly income spent on food (Table 2.8). Results indicated more households incomes (>21%) were spent on food procurement in the previous month (60.5%). In the same vein, more than 21% of household incomes were spent on food (56.9).

Table 2.8: Average income spent on food

Variables	Scale	Frequency	Percentage
Previous month	5-10%	43	17.0
	11-20%	57	22.5
	21%+	153	60.5
Last year	5-10%	64	25.3
	11-20%	45	17.8
	21%+	144	56.9
Past five years	5-10%	52	20.6
	11-20%	100	39.5
	21%+	101	39.9
Past 10 years	5-10%	69	27.3
	11-20%	184	72.7

Source: Fieldwork, May 2022

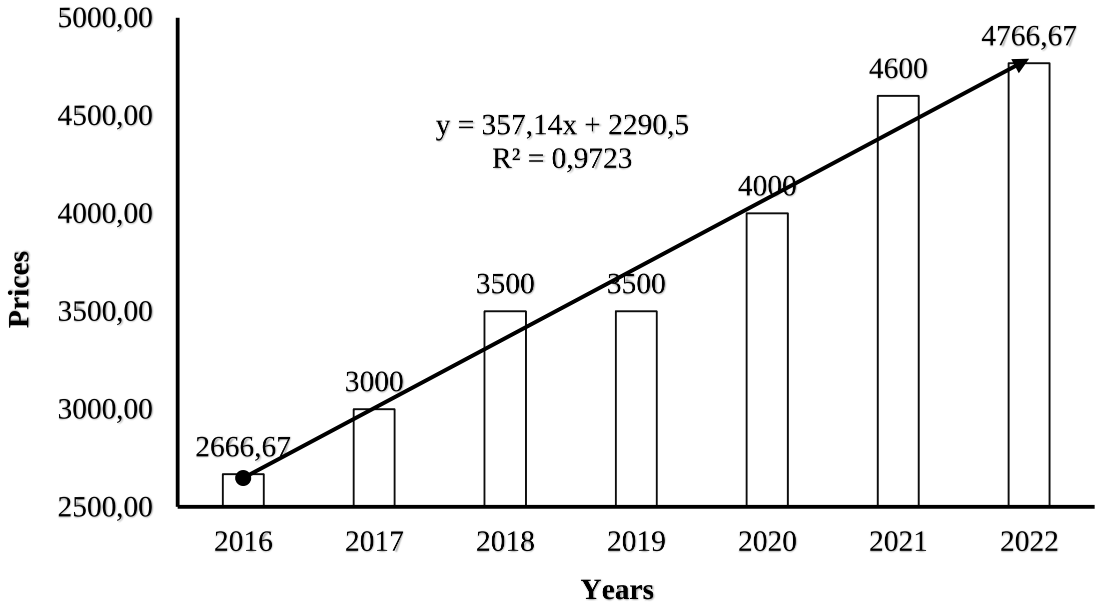
With the onset of the Anglophone crises, the population indicated that they were spending 11-20% and more that 21% of their incomes on food (39.5% and 39.9% respectively). In the past 10 years, 11-20% of household incomes were spent on food. The increase in prices of basic necessities including food crops has been alarming in markets in Bamenda II Sub-division. Maize prices have also been in the same trend (Table 2.9).

Table 2.9: Evolution of maize prices per 15 litres bucket in markets in Bamenda II Sub-division

Markets	Years and prices (FFCA)						
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Ntarikon Market	2500	3000	3500	3500	4000	4500	5000
Food Market	2500	3000	3500	3500	4000	4500	4500
Main Market	3000	3000	3500	3500	4000	4800	4800
Average	**2666.67**	**3000**	**3500**	**3500**	**4000**	**4600**	**4766.67**

Source: Fieldwork, September 2022

The average price of a 15 litres bucket of dry corn has increase from 2666.67 to 4766.67 FCFA from 2016 to 2022, giving an increase of 21% increase within seven years. Within the framework of an uncertain climate and volatility of other maize production inputs, there are no signs that prices will reduce.



Source: Table 2.9

Figure2. 17: Evolution of maize prices in markets in Bamenda II Sub-division

2.13 Statistical Evaluation of rainfall and temperature variations on maize production

The hypothesis that guided this chapter was that the variation in rainfall and temperature does not significantly affect maize production in Bamenda II. The Pearson Product Moment Correlation was used in verifying this hypothesis (Table 2.10).

Table 2.10: Pearson Product Moment Correlation for rainfall, temperature and maize yields

Variables	Correlations	Rainfall variability	Temperature variability	Maize yields
Rainfall variability	Pearson Correlation	1		
	Sig. (2-tailed)			
	Sum of Squares	443.510		
	Covariance	1.760		
	N	253		
Temperature variability	Pearson Correlation	-.144*	1	
	Sig. (2-tailed)	.022		
	Sum of Squares	-38.530	161.589	
	Covariance	-.153	.641	
	N	253	253	
Maize yields	Pearson Correlation	-.016	-.029	1
	Sig. (2-tailed)	.797	.643	
	Sum of Squares	-4.403	-4.791	165.249
	Covariance	-.017	-.019	.656
	N	253	253	253

The interactive frequency for the variables is 1.760 for rainfall variability and -.153 for temperature variability with p-value of 0.022 and 0.797. Since the p-value for maize production in Bamenda II is greater than the p-value for rainfall and temperature variability and the standard p-value of 0.5, the researcher therefore accepts the hypothesis.

2.14 Conclusion

Agriculture is very important to the economy of Cameroon at large and should be improving upon so as to enhance food security. So many parts of the world today especially those in the developing countries is hit by food insecurity which is mainly due to the constraints affecting the smooth functioning of the agricultural sector. Reduction in hunger is driven by projected socioeconomic development. Most agricultural practices especially in Africa depends on rained agriculture for their livelihoods, therefore the tendency of food insecurity may likely be upward projection. There is therefore serious need to protect the environment against human activities that affect the rainfall pattern especially those activities contributing to climate variability. The understanding of the relationship between climate and agriculture will enable agriculturalists or farmers to fit crops to climate and avoid unpleasant consequences of agricultural planning and development.

CHAPTER THREE

ADAPTATION TO CLIMATE VARIABILITY IN THE MAIZE PRODUCTION SECTOR OF BAMENDA II

3.0 Introduction

This chapter evaluates the existing climate adaptation strategies practiced by farmers to fight against food insecurity in Bamenda II. The specific hypothesis here states that adaptation measures implemented by farmers have significantly reduced maize farmer's vulnerability to climate variability and increase food production. The results are segmented into observed adaptation practices (agroforestry, micro-irrigation schemes, indigenous soil and water conservation, alteration of planting dates and use of improved seeds). Furthermore, adaptation strategies are complemented with the sustainable livelihood assets (social, natural, financial, physical and human capital). The chapter wraps with barriers to climate adaptation in the maize production sector of Bamenda II Sub-division.

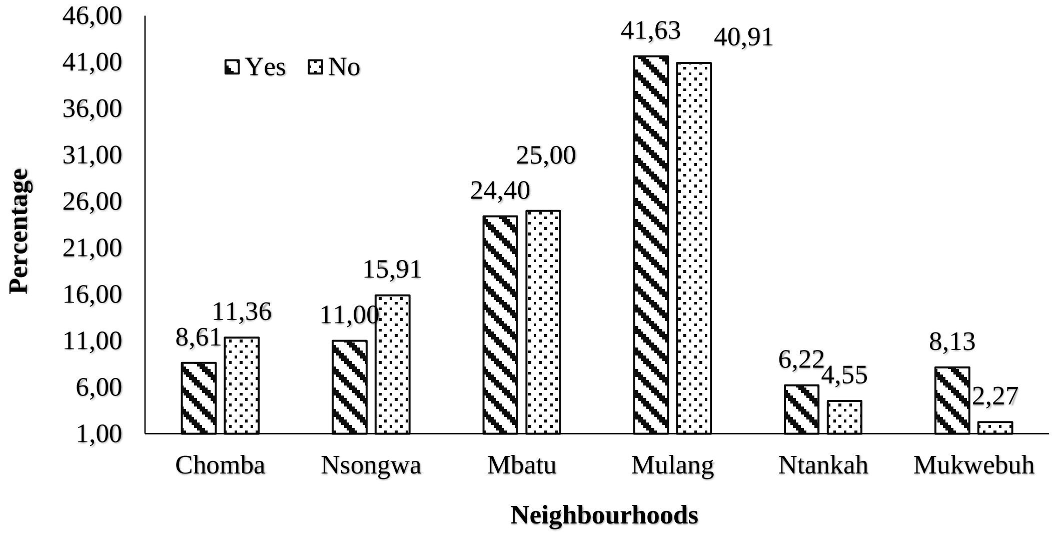
3.1 Adaptation to climate variability in the maize production sector

Lobell and Schlenka (2016) established the impacts of climate variability on agricultural production using a scientific literature. Natural extremes and anomalies in weather conditions at the global level, a trend that is expected to continue as temperatures further rise. According to this concept, if no adaptation to climate variability takes place; global agricultural yields are expected to decrease at a pace of 1.5% per decade (Gourdji, 2015). Not only the impacts of climate on food production may vary across space (Iglesias et al., 2012), but countries' adaptive capacity to weather shocks is unlikely to be spatially homogeneous and rather differs across locations and strata of the populations within the same country (Alam, 2017).

One key aspect that can restrain a country's resilience to climate variability is represented by the spatial distribution of food; the negative impacts of climate variability are likely to increase relative differences in food access and supply at both the global and local levels, as the degree of climate variation and the extent of its impacts on populations will differ from one community to another, and between rural and urban areas (Wheeler and von Braun, 2013). The various strategies applied in Bamenda II Municipality to adapt maize production to climate variability include agroforestry practices, micro-irrigation schemes, indigenous soil and water conservation, changing planting dates and use of improved seeds.

3.1.1 Agroforestry practices

Ensuring agro-forestry practices is one of the strategies applied in Bamenda II to adapt maize cultivation in particular and agriculture in general. Agro-forestry aims at preventing or limiting soil erosion and also protects the environment against climate variability and change. The strategy is however applied at different scales within the municipalities in Bamenda II (Figure 3.1).



Source: Fieldwork, May 2022

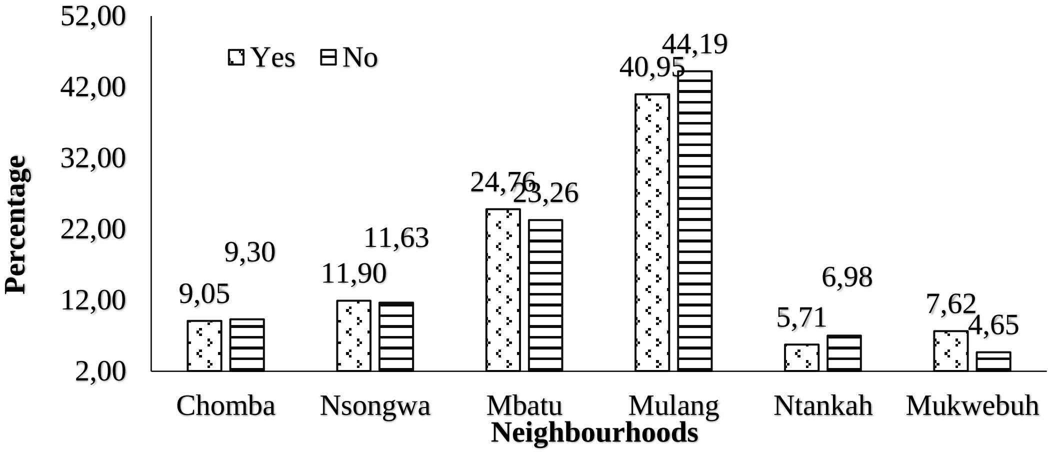
Figure 3. 1:Agroforestry practices in Bamenda II Sub-division

In Chomba, this strategy is applicable at 8.61%, Nsongwa (11%), Mbatu (24.4%), Mulang (41.63%), Ntankah (6.22%) and Mukwebuh (8.13%). Overall, farmers in Bamenda II are proactive to agroforestry. Some of the farmers are gradually integrating fruit trees with food crops so as to boost their incomes.

3.1.2 Micro-irrigation schemes

Micro-irrigation schemes are also carried as a means to adapt crop cultivation to climate variability in Bamenda II (Figure 3.2). Results indicated that this practice stands at 9.05% in Chomba, Nsongwa (11.9%), Mbatu (24.76%), Mulang (40.95%), Ntankah (5.71%) and Mukwebuh (7.62%). The success of micro-irrigation in a location like Mulang is as result of its proximity to the tributaries of River Mezam.

Photo 3. 1: The use of irrigation to overcome drought in Mulang



Source: Fieldwork, May 2022

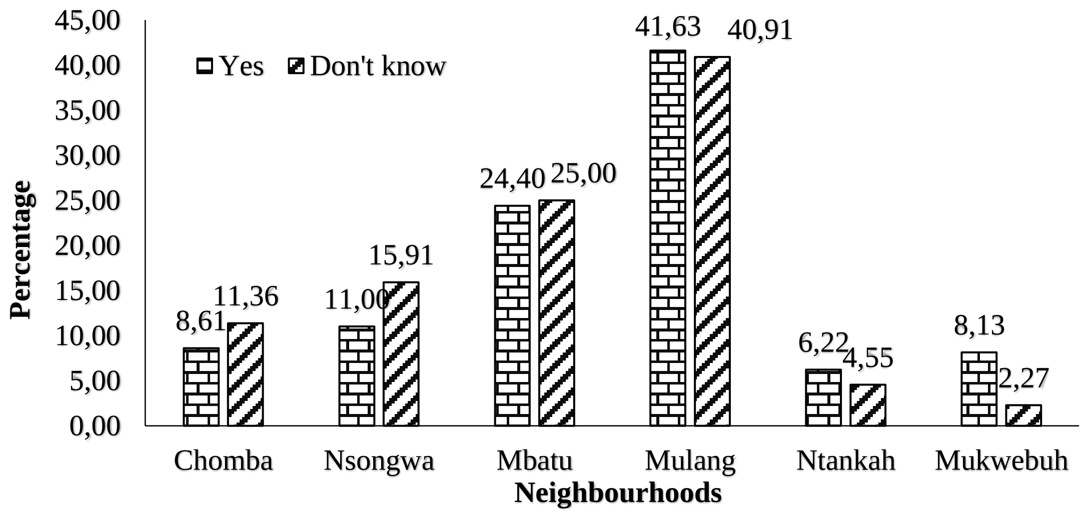
Figure 3. 2: Micro-irrigation schemes in Bamenda II Sub-division

Micro-irrigation schemes aim at providing water for crop cultivation. This is done especially in the dry season for the cultivation of market gardening crops such as tomatoes and green spices. Maize is also cultivation in the dry season by some farmers with water from irrigation schemes. The main reason for this low practice of irrigation highlighted by the farmers is the high cost involved in carrying out the activity. The few farmers in the area that carries out irrigation are mostly those that practice market gardening since market gardening crops like tomatoes needs much water for growth. Other adaptation strategies include migrating to closer taps and streams for water, investing more on livestock farming and genetically modifying seeds to make them good for adaption.

3.1.3 Indigenous soil and water conservation

Soil conservation and mulching is critical to the adaptive strategies to climate variability and change. The implementation of indigenous soil and water conservation schemes is also carried as a means to adapt crop cultivation to climate variability in Bamenda II (Figure 3.3). Results revealed that that this practice is relatively slow in the study area. In Chomba, this practice stands at 8.61%, Nsongwa (11%), Mbatu (24.4%), Mulang (41.63%), Ntankah (6.22%) and Mukwebuh (8.13%).

Indigenous soil and water conservation strategies include the application of organic manure in farms. Natural water sources like streams are also protected so as to get water for irrigation. Soil conservation is the prevention of loss of the top most layer of the soil from soil erosion or prevention of reduced fertility caused by over usage, acidification, stalinization or other chemical soil conservation.



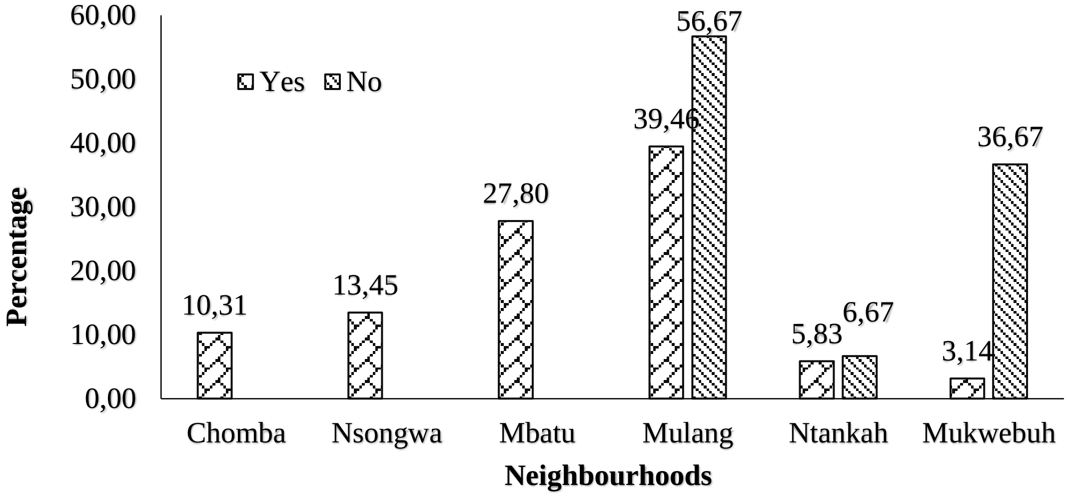
Source: Fieldwork, May 2022

Figure3. 3: Indigenous soil and water conservation in Bamenda II Sub-division

Slash-and-burn and other unsustainable methods of subsistence farming are practiced in the study area. Techniques to improve soil conservation include crop rotation, cover cropping, which affects both erosion and fertility. Mulching is a practice of covering the top soil with organic materials like straw, grass, stones inorganic materials like plastic.

3.1.4 Changing planting dates

Farmers in Bamenda II Sub-division alter or changes planting dates so as to adapt crop cultivation to climate variability (Figure 3.4).



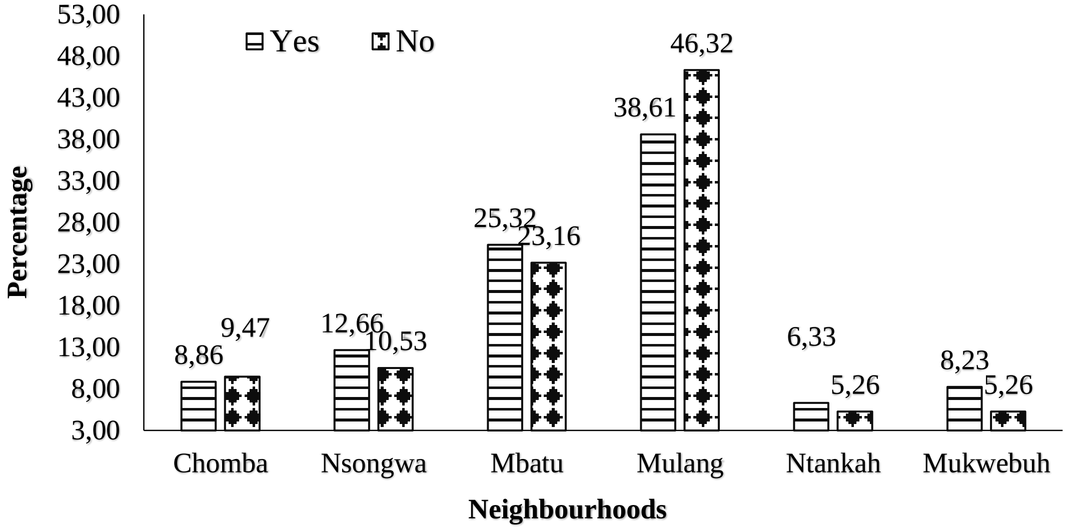
Source: Fieldwork, May 2022

Figure3. 4: Changing planting dates in Bamenda II Sub-division

Results revealed that changing planting dates stand at 10.31% in Chomba, Nsongwa (14.45%), Mbatu (27.8%), Mulang (39.46%), Ntankah (5.83%) and Mukebuh (3.14%). Climate variability in Bamenda often results to late or early onset of first rains. Farmers therefore alter or changes planting dates depending on the onset of first rains. Understanding how farmers perceive climate variability and how they adapt to it is very important to the implementation of adequate policies for agricultural and food security. Farmers in Bamenda II Municipality have applied different strategies to adapt to the changing climate. Agricultural productivity is measured as the ratio of agricultural outputs to agricultural inputs. While individual products are usually measured by weight, their varying densities make measuring overall agricultural output difficult.

3.1.5 Use of improved seeds

Farmers also plant genetically improved seeds as a method of adapting crop cultivation to climate variability (Figure 3.5). Farmers are gradually embracing the use improved seeds, which may be resilient to adverse weather conditions. Results revealed that this adaptation stands at 8.86% in Chomba, Nsongwa (12.66%), Mbatu (25.35%), Mulnag (38.61%), Ntankah (6.33%) and Mukwebuh (8.23%).



Source: Fieldwork, May 2022

Figure3. 5: Use of improved seeds in Bamenda II Sub-division

Some of these improved maize species are ATP, PANNAR and Coca. Drought resilient seeds help the crops grow and be resilient to climate variability and change. This is appropriate as these seeds can be considered as drought tolerant and are able to thrive under harsh environmental conditions. This shows that the crops can strive to grow in periods of late on set of early rains in Bamenda II Sub-division.

3.2 Sustainable Livelihood Assets for climate adaptation

The various livelihood assets for climate adaption include social capital, natural capital, financial capital, physical capital and human capital.

3.2.1 Social capital

The capital needed for climate adaptation is gotten from social groups such as membership of a cooperative, membership of a njangi group and member of a CIG (Table 3.1).

Table 3.1: Social capital assets for climate adaptationin Bamenda II Sub-division

Neighbourhood	Yes		No	
	F	%	F	%
Membership of a cooperative				
Chomba	11	9.09	12	9.09
Nsongwa	12	9.92	18	13.64
Mbatu	29	23.97	33	25.00
Mulang	50	41.32	55	41.67
Ntankah	8	6.61	7	5.30
Mukwebuh	11	9.09	7	5.30
Membership of a njangi group				
Chomba	23	9.09	0	0
Nsongwa	30	11.86	0	0
Mbatu	62	24.51	0	0
Mulang	105	41.50	0	0
Ntankah	15	5.93	0	0
Mukwebuh	18	7.11	0	0
Member of a CIG				
Chomba	14	8.43	9	10.34
Nsongwa	18	10.84	12	13.79
Mbatu	41	24.70	21	24.14
Mulang	68	40.96	37	42.53
Ntankah	10	6.02	5	5.75
Mukwebuh	15	9.04	3	3.45

Source: Fieldwork, May 2022

Membership of a cooperative serves as one of the strongest social networks where farmers and other stakeholders operate thrift and loan schemes for diverse activities. Farmers in Chomba indicated that their level of operation is 9.09%, Nsongwa (9.92%), Mbatu (23.97%), Mulang (41.32%), Ntankah (6.61%) and Mukwebuh (9.09%). Concerning membership of njangi groups (weekly or monthly savings and loan schemes), the responses were as follows: Chomba (9.09%), Nsongwa (11.86%), Mbatu (24.51%), Mulang (41.5%), Ntankah (5.93%)

and Mukwebuh (7.11%). Farmers have also affiliated to CIGs for common interests. The results were as follows: Chomba (8.43%), Nsongwa (10.84%), Mbatu (24.7%), Mulang (40.96%), Ntankah (6.02%) and Mukwebuh (9.04%).

There exist many producer cooperatives in Bamenda II that assist farmers in different ways, directly and indirectly helping in adaptation to climate variability for food security (Table 3.2).

Table 3.2: Cooperative societies and their activities in Bamenda II

Cooperative	Activities
Fish Farmers Cooperative Society	Aquaculture
Alamato Cooperative Credit Union Limited	Thrifts and loans
Atiah Cameroon Cooperative Credit Union Limited	Thrifts and loans
Integrated Fish Farmers Simplified Cooperative Society	Aquaculture
Mbamba Cooperative Credit Union Limited	Thrifts and loans
Ntumbeny Cooperative Credit Union Limited	Thrifts and loans
One Seed One Farm Organic Farmers Cooperative Society	Crop production and marketing
Alamankon Farmers' Cooperative Society	Crop production and marketing
Ntarinkon Cooperative Society Credit Union	Thrifts and loans
God's Favour Integrated Simplified Cooperative Societies	Crop production and marketing
Nitop I Vegetable Producers Cooperative Society	Vegetable production and commercialization
CABA Agro-Pastoral Inter-Professional Farmers Marketing Cooperative Society	Livestock production, processing and commercialization
Cameroon Seed Simplified Cooperative Society	Seed multiplication and commercialization
Young Entrepreneurs Start-up Cooperative Society	Coaching of young agripreneurs
Persons With Disabilities Credit Union Limited	Crop production and marketing
Fidelity Cooperative Investment Limited	Crop production and marketing
AJ Integrated Farm Cooperative Society	Crop production and marketing

Beckeys Dynamic Inter-Professional Agro-Pastoral Cottage Industry Cooperative Society	Livestock production, processing and commercialization
Muwacho Youths Integrated Simplified Cooperative	Crop production and marketing

Source: Bamenda II Council, 2022

These societies bring farmers together for a common purpose of pulling resources together for the benefit of their members.

3.2.2 Natural capital

Farmers also adapt to climate by using water from streams and water reservoirs or when there is available land to grow crops, keep livestock and road networks (Table 3.3).

Table 3.3: Natural capital assets for climate adaptation in Bamenda II Sub-division

Neighbourhoods	Yes		No	
	F	%	F	%
Streams and water reservoirs				
Chomba	12	9.09	11	9.09
Nsongwa	18	13.64	12	9.92
Mbatu	33	25.00	29	23.97
Mulang	55	41.67	50	41.32
Ntankah	7	5.30	8	6.61
Mukwebuh	7	5.30	11	9.09
Land to grow crops, keep livestock, road networks				
Chomba	11	9.09	12	9.09
Nsongwa	12	9.92	18	13.64
Mbatu	29	23.97	33	25.00
Mulang	50	41.32	55	41.67
Ntankah	8	6.61	7	5.30
Mukwebuh	11	9.09	7	5.30

Source: Fieldwork, May 2022

Water use for irrigation from streams and other reservoirs for maize production and other crops during the dry season revealed results as follows: Chomba (9.09%), Nsongwa (13.64%), Mbatu (25%), Mulang (41.47%), Ntanka (5.3%) and Mukwebuh (5.3%). Available land to grow crops, keep livestock and road networks had the following results: Chomba (9.09%), Nsongwa (9.92%), Mbatu (23.97%), Mulang (41.32%), Ntanka (6.61%) and Mukwebuh (9.09%).

3.2.3 Financial capital

Funds for agricultural activities in Bamenda II are also gotten from micro-finance institutions (Table 3.4). Results revealed that the availability of grants, loans and credit available to rural farmers stood at 9.62% for Chomba, Nsongwa (9.62%), Mbatu (23.08%), Mulang (48.08%), Ntankah (3.85%) and Mukwebuh (5.77%). Reliance on pension money and other social grants to offset food insecurity had the following results: Chomba (9.3%), Nsongwa (11.63%), Mbatu (23.26%), Mulang (44.19%), Ntankah (6.98%) and Mukwebuh (4.65%). Availability of credits and funding for farming endeavors to alleviate food insecurity had the following results: Chomba (9.62%), Nsongwa (9.62%), Mbatu (23.08%), Mulang (48.08%), Ntankah (3.85%) and Mukwebuh (5.77%).

Table 3.4: Financial capital assets for climate adaptationin Bamenda II Sub-division

Neighbourhoods	**Yes**		**No**	
	F	**%**	**F**	**%**
Availability of grants, loans and credit available to rural farmers				
Chomba	5	9.62	18	8.96
Nsongwa	5	9.62	25	12.44
Mbatu	12	23.08	50	24.88
Mulang	25	48.08	80	39.80
Ntankah	2	3.85	13	6.47
Mukwebuh	3	5.77	15	7.46
Pension money and social grants are sufficient to offset food insecurity				
Chomba	4	9.30	19	9.05
Nsongwa	5	11.63	25	11.90
Mbatu	10	23.26	52	24.76
Mulang	19	44.19	86	40.95
Ntankah	3	6.98	12	5.71

Mukwebuh	2	4.65	16	7.62
Enough credit and funding for farming endeavors				
Chomba	5	9.62	18	8.96
Nsongwa	5	9.62	25	12.44
Mbatu	12	23.08	50	24.88
Mulang	25	48.08	80	39.80
Ntankah	2	3.85	13	6.47
Mukwebuh	3	5.77	15	7.46

Source: Fieldwork, May 2022

The various sources of financial capital for climate adaptation include the availability of grants, loans and credit available to rural farmers, pension money and social grants are sufficient to offset food insecurity and available credit and funding for farming endeavors.

3.2.4 Physical capital

The physical capital in crop cultivation can be seen in terms of farming tools like tractors and other machineries needed for crop cultivation (Table 3.5). Results indicated that the size of the land is too small, and the quality of the soil is poor for farming as follows: Chomba (8.96%), Nsongwa (12.44%), Mbatu (24.88%), Mulang (39.80%), Ntankah (6.47%) and Mukwebuh (7.46%).

Table 3.5: Physical capital assets for climate adaptationin Bamenda II Sub-division

Neighbourhoods	Yes		No	
	F	%	F	%
Tractors and essential mechanization for crop farming				
Chomba	0	0	23	9.09
Nsongwa	0	0	30	11.86
Mbatu	0	0	62	24.51
Mulang	0	0	105	41.50
Ntankah	0	0	15	5.93
Mukwebuh	0	0	18	7.11
Size of the land is too small, and the quality of the soil is poor for farming				

Chomba	18	8.96	5	9.62
Nsongwa	25	12.44	5	9.62
Mbatu	50	24.88	12	23.08
Mulang	80	39.80	25	48.08
Ntankah	13	6.47	2	3.85
Mukwebuh	15	7.46	3	5.77

Source: Fieldwork, May 2022

Physical capital in Bamenda II is limited for crop cultivation in terms of tractors and essential mechanization for crop farming. This is however limited by the capital and the size of land too small as the farmers indicated that they do not use tractors. The quality of the soil is also considered poor for farming which discourages the farmers from investing physical capital in maize production in particular and other crops in general.

3.2.5 Human capital

The human capital for crop cultivation in Bamenda II is seen in terms of more education to better understand and mitigate the impact of climate variability on food security, capacity and skills to work on the lands, youth engagement and women are majority of farmers (Table 3.6).An important component of human capital is more education building to better understand and mitigate the impact of climate variability on food security, which had the following results: Chomba (11.17%), Nsongwa (13.59%), Mbatu (8.25%), Mulang (50.97%), Ntankah (7.28%) and Mukwebuh (8.74%).

Climate change education is extended to include capacity building and skills to work on the land and youth engagement in crop cultivation. The results were as follows: Chomba (8.86%), Nsongwa (12.66%), Mbatu (25.32%), Mulang (38.61%), Ntankah (6.33%) and Mukwebuh (8.23%).

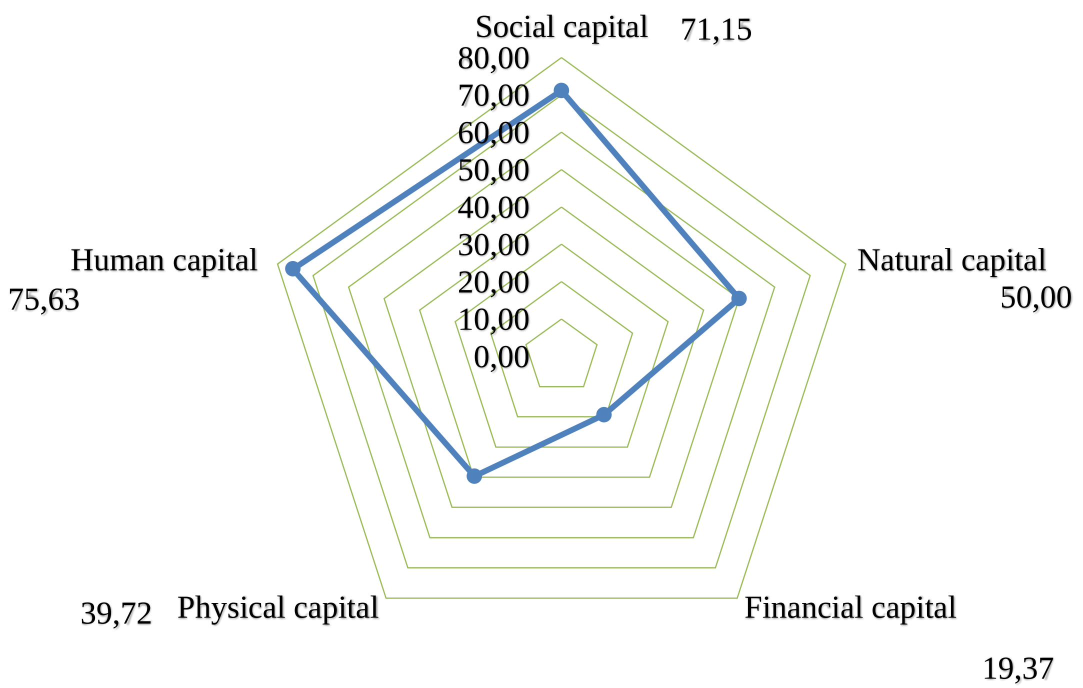
Table 3.6: Human capital assets for climate adaptationin Bamenda II Sub-division

Neighbourhoods	Yes		No	
	F	**%**	**F**	**%**
More education to better understand and mitigate the impact of climate variability on food security				
Chomba	23	11.17	0	0.00
Nsongwa	28	13.59	2	4.26
Mbatu	17	8.25	45	95.74
Mulang	105	50.97	0	0.00
Ntankah	15	7.28	0	0.00
Mukwebuh	18	8.74	0	0.00
Capacity and skills to work on the lands, youth engagement				
Chomba	14	8.86	9	9.47
Nsongwa	20	12.66	10	10.53
Mbatu	40	25.32	22	23.16
Mulang	61	38.61	44	46.32
Ntankah	10	6.33	5	5.26
Mukwebuh	13	8.23	5	5.26
Women are majority of farmers				
Chomba	19	9.05	4	9.30
Nsongwa	25	11.90	5	11.63
Mbatu	52	24.76	10	23.26
Mulang	86	40.95	19	44.19
Ntankah	12	5.71	3	6.98
Mukwebuh	16	7.62	2	4.65

Source: Fieldwork, May 2022

Women are majority of farmers in Bamenda II, with the following results: Chomba (9.05%), Nsongwa (11.9%), Mbatu (24.76%), Mulang (40.95%), Ntankah (5.71%) and Mukwebuh (7.62%).

Based on some projections such as the climate reality project, changes in temperature, rainfall and severe weather events are expected to reduce crop yield in many regions of the developing world, particularly sub-Saharan Africa and parts of Asia. The impact of climate variability on agriculture tends to be more severe for countries with higher initial temperatures, areas with marginal or already degraded lands and lower levels of development with little adaptation capacity.Climate variability is a global issue that does not respect national borders. It is an issue that has reached national level and it requires international cooperation to help Developed countries move toward a low carbon economy.Sustainable livelihood assets act as a strong back-up to climate adaptation in agriculture and other sectors. In Bamenda II Sub-division, the adaptive capacity of farmers has been weakened by inadequate financial resources (19.37%) and physical capital (39.72%) (Figure 3.6).



Source: Fieldwork, May 2022

Figure3. 6: Sustainable Livelihood Assets for climate adaptation in Bamenda II

The effect of climate is especially detrimental in those countries that are dependent on agriculture and where food production is concentrated in few areas. Schematically, the line of reasoning proposed in the article proceeds as follows: climate anomalies (warm spells, droughts) have a heterogeneous effect on crop production across locations, leading to a disproportionate harvest decrease in some regions compared to others. Spatially heterogeneous crop failures will disproportionately restrain local populations' access to food, reduce rural households' means of sustenance, and induce peaks in food prices which reduce consumers' purchasing power (Berazneva and Lee, 2013).

This affects agricultural income (Roche et al., 2020), leading to a heavier deterioration of the local livelihood in some regions, while others are relatively better off. The relative deprivation induced by heterogeneous livelihood impairment and shifts in food entitlements will in turn:

(a) Foster grievances, especially when intertwining with extant societal fractures or ethnic exclusion (Ide, 2021).

(b) Trigger resource competition and deliberate efforts to deny adversaries' access to harvests (Linke and Ruether, 2021), and decrease the opportunity cost of conflicts for the poor and thereby motivate the use of collective violence and increase the predisposition to armed conflict.

Another successful adaptation plan for climate change is through advocacy by Civil Society Organizations (CSOs). The Bamenda II Sub-division can be described as the hub of CSOs in the North West Region of Cameroon. Their activities span across different aspects of environment and development (Table 3.7)

Table 3.7: Some Civil Society Organizations and their environmental activities in Bamenda II

Name	Activities
Center for Indigenous Resources Management and Development (CIRMAD)	Climate change mainstreaming, biodiversity management
Community Service for Nature and Environmental Sustainability (COSENES)	Water catchment protection and tree nursery establishment
Society for Initiatives in Rural Development and Environmental Protection (SIRDEP)	Environmental education, tree planting, water catchment protection, community forest management and agroforestry

Nkwenti Environmental Protection Foundation	Waste management
Ozone Friendly People (OFP)	Watershed protection, tree planting, EIN consult
Crusaders for Environmental Protection and Ozone Watch (CEPOW)	Forest resource management, rural community development, environmental education, waste management
Green Environmental and Engineering Consult	Landscaping, greening, design
Rural Women Center for Education and Development (RuWCED)	Environmental education, women's health and women empowerment
Community Initiative for Sustainable Development (COMINSUD)	Sustainable development, women empowerment, rural development, peace building
Cameroon Renewable Energy (CAMREFE)	EIA and waste management clean cook stoves
Better World Foundation	Sustainable development activities
Community Agriculture and Environmental Protection Project Cameroon (CAEPP-CAM)	Environmental protection and sustainable agriculture
Association of Environmental Education Teachers and School Environmental Clubs (ASEC-NW)	Environmental Education
Participatory Assessment of Development (PADEV)	Participatory assessment of development
Organization for integrated Rural Development (ORIRUDEV)	Organization for Integrated Rural Development
Mushroom Production Training and Research Centre	Mushroom production, training and research

(MUPTAREC)	

Source: Regional Delegation of Environment, Nature Protection and Sustainable Development, 2022

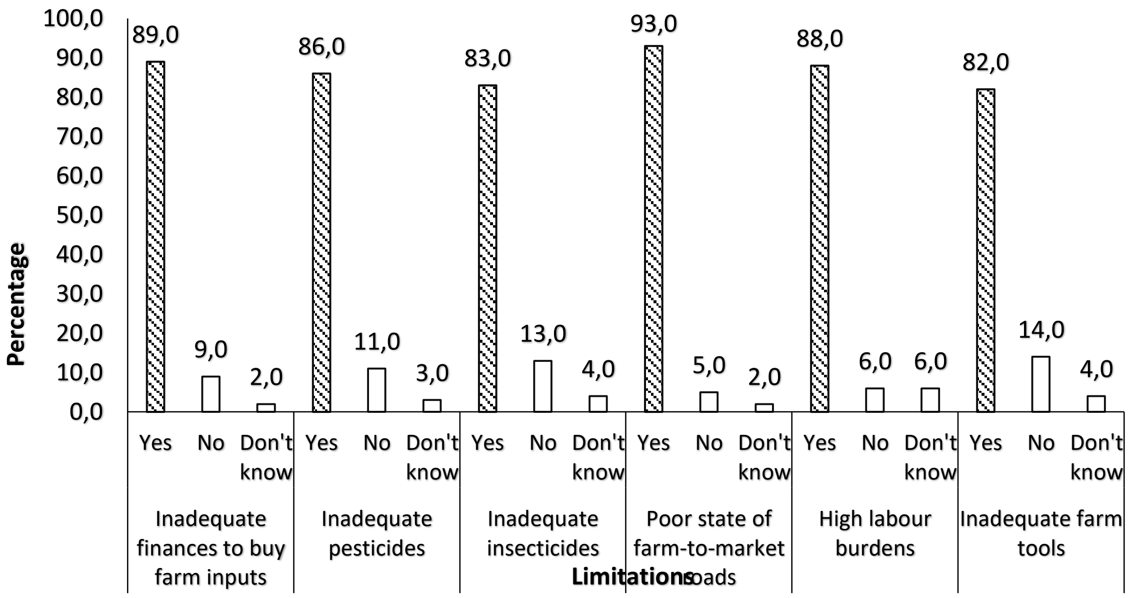
These civil society organizations promote sustainable environmental management practices. Farmers that have embraced them are gradually shifting towards a climate-smart system to ensure food security.

3.3 Barriers to adaptation

Despite strategies used to overcome climate variability and food security, the farmers still face challenges that make it difficult for them to adapt. These barriers are grouped into economic and institutional barriers, as well environmental and social constraints.

3.3.1 Economic and Institutional Constraints

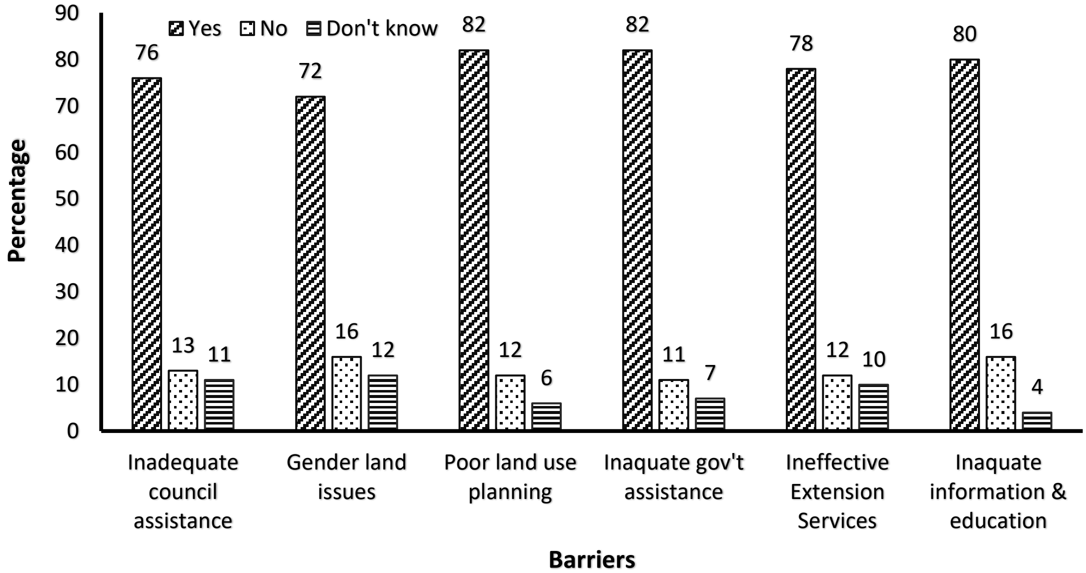
When considering economic barriers, inadequate finances to buy farm inputs is considered by a majority (89%) of the farmers to be a hindrance to their adaptability strategies to improve on crop production (Figure 3.7). Eighty-six (86%) of the farmers consider inadequate pesticides to be a barrier to crop production, 83% said inadequate insecticides, 93% of the farmers said poor state of farm-to-market roads, 88% said high labour burdens and finally 82% agreed that inadequate farm tools are a barrier to crop production.



Source: Fieldwork, May 2022

Figure3. 7: Economic barriers to crop production in Bamenda II

Institutions are also a hindrance to the adaptation of strategies by crop farmers. Results revealed that 76% of the farmers they do not receive adequate assistance from the Bamenda II Council (Figure 3.8). Gender inequality in land matters it's a barrier to crop production contributes to 72% of the barriers, while 82% agreed that poor land use planning is also a barrier to crop production. Again, 82% of the population agreed that inadequate government assistance is a hindrance to crop production and 78% of the farmers agreed that ineffectiveness of agricultural technicians and extension field workers is a hindrance to crop production.



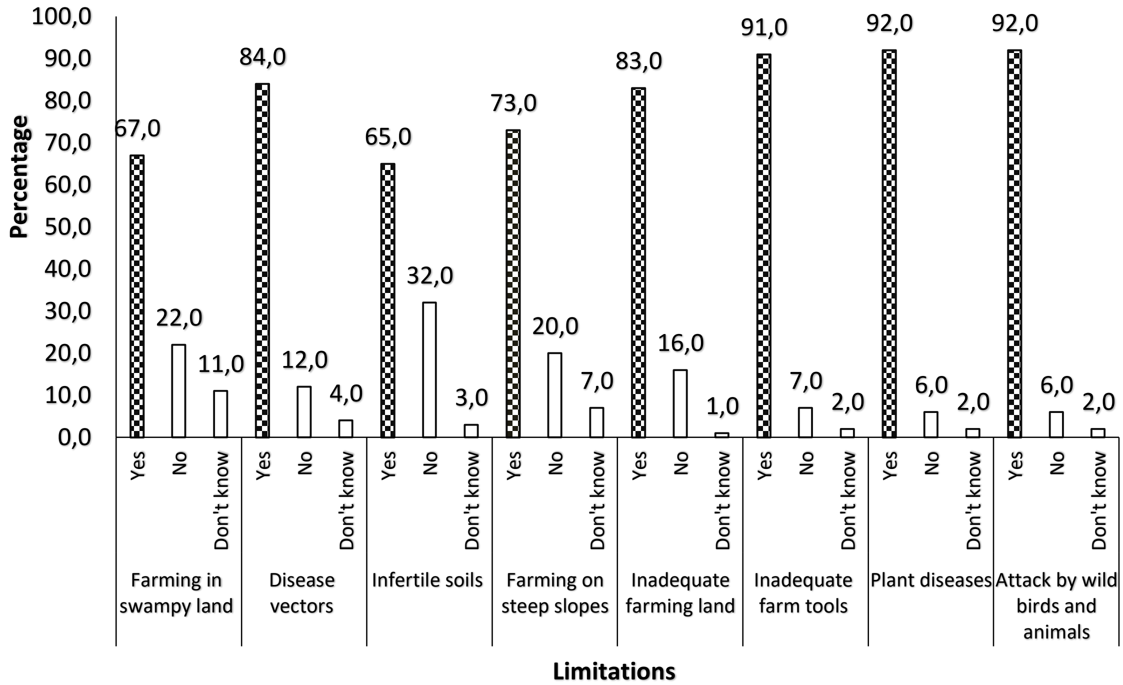
Source: Fieldwork, May 2022

Figure3. 8: Institutional barriers to crop production in Bamenda II

Finally, 80% of the population agreed that inadequate information and low level education contribute as barriers to adaptation of farmers to strategies to improve crop production.

3.3.2 Environmental and Socio-economic Constraints

Environmental barriers to crop production include Farming in swampy land as agreed by 67% of the farmers. With respect to disease vectors 84% of the population agreed that it's a barrier to crop cultivation, 65% agreed that infertile soils are a hindrance to crop production (Figure 3.9).

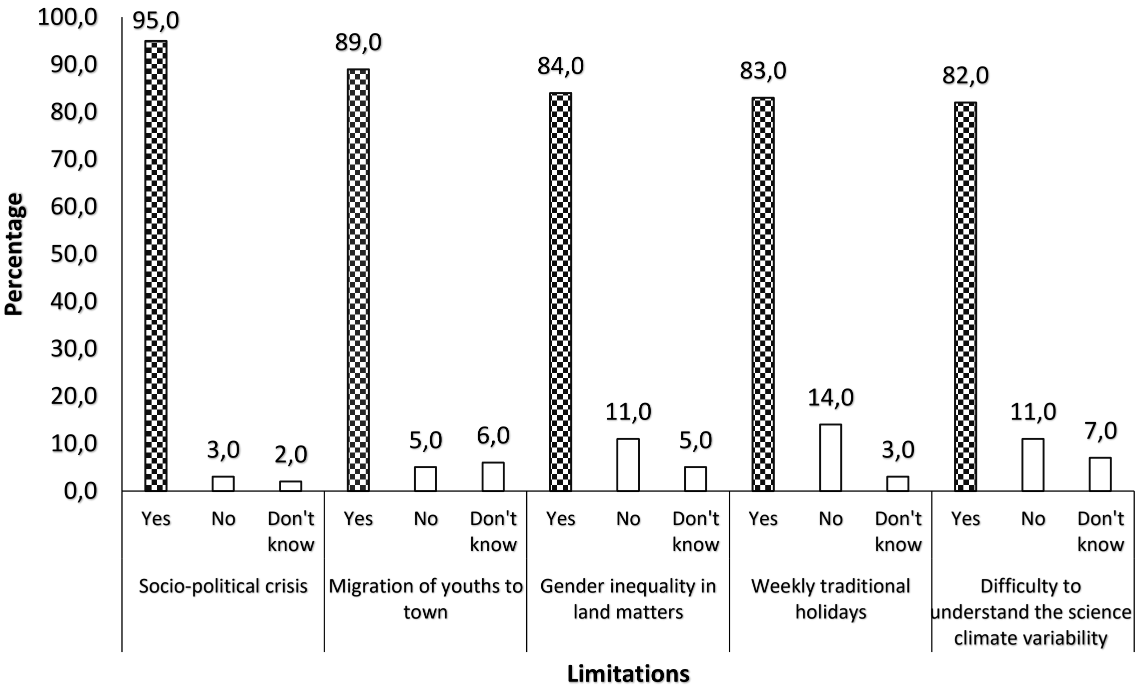


Source: Fieldwork, May 2022

Figure 3. 9: Environmental barriers to crop production in Bamenda II

A total of 73% of the farmers indicated that farming on steep slopes is one of the barriers, 83% considered inadequate farming land as one of barriers, 91% of the population agreed that inadequate farm tools 92% of farmers agreed that plant diseases is a major barrier to crop production. While 92% of the farmers finally accepted that the attack by wild birds and animals contribute to the barriers of crop production.

Results revealed that 89% of the farmers agreed that migration of youths to town has reduced the production of crop in Bamenda II. Eighty-four (84%) agreed that gender inequality in land matters is also barrier to crop production in Bamenda II (Figure 3.10).



Source: Fieldwork, May 2022

Figure 3. 10: Socio-cultural barriers to crop production in Bamenda II

Eighty-three (83%) agreed that cultural constraints such as weekly traditional holidays reduce the quantity of crops and finally 82% of the farmers compliant that their difficulty to understand the science climate variability and adaptation is one of their major barriers in crop production. In the Mankon Fondom, no outdoor activities are carried out on '**Mbi'nƏ'**, while in Chomba, no outdoor activities are carried out on '**Ŋgwəŋduŋə'** and '**Ziŋkon'**.

Farmers are experiencing the need to adapt to climate variability and are developing different strategies. This study contributes to the understanding of farmer's adaptation choices, their determinants and their implementation. One of the widest spread anthropogenic challenges affecting agricultural production is climate variability. An adjustment to the actual or expected changes has to be therefore among priorities in policy decisions. Farmers behavioral change towards adaptation and willingness to take action are important as are policy decisions. The need for adaptation to ensure food security particularly is highly justified and supported at the political and policy levels. These policy level adaptation needs are insufficiently supported by local farmer's choices. The various limitations to farmer's adaptation to climate variability in Bamenda II Sub-division are inadequate capital, poor state of farm to market roads, difficulty to understand the science of climate variability and infertile soils.

3.4 Agricultural Land use Responses (1984-2022)

The barriers to climate adaptation are cumulatively constrained by urbanization in Bamenda II Sub-division. Urbanization and agriculture are incompatible land use as they are detrimental to each other. Urban agriculture occupies insignificant spaces like small gardens around homesteads. The main land cover/ land uses for Bamenda II (1984-2022) are built-up area, farmlands, grassland, remnants of forest cover and water bodies (Table 3.7).

Table 3.7: Land cover/use categories in Bamenda II (1984-2022)

Land cover/use	1984	2003	2013	2022
Built-up	830.07	1386	2551.59	3027.15
Farmlands	5304.24	6488.64	4608.09	5165.28
Grassland	5224.05	4911.66	1559.7	2741.31
Forest	5813.91	4387.59	8447.13	6237
Water bodies	17.19	15.57	22.95	18.72
Total	17189.46	17189.46	17189.46	17189.46

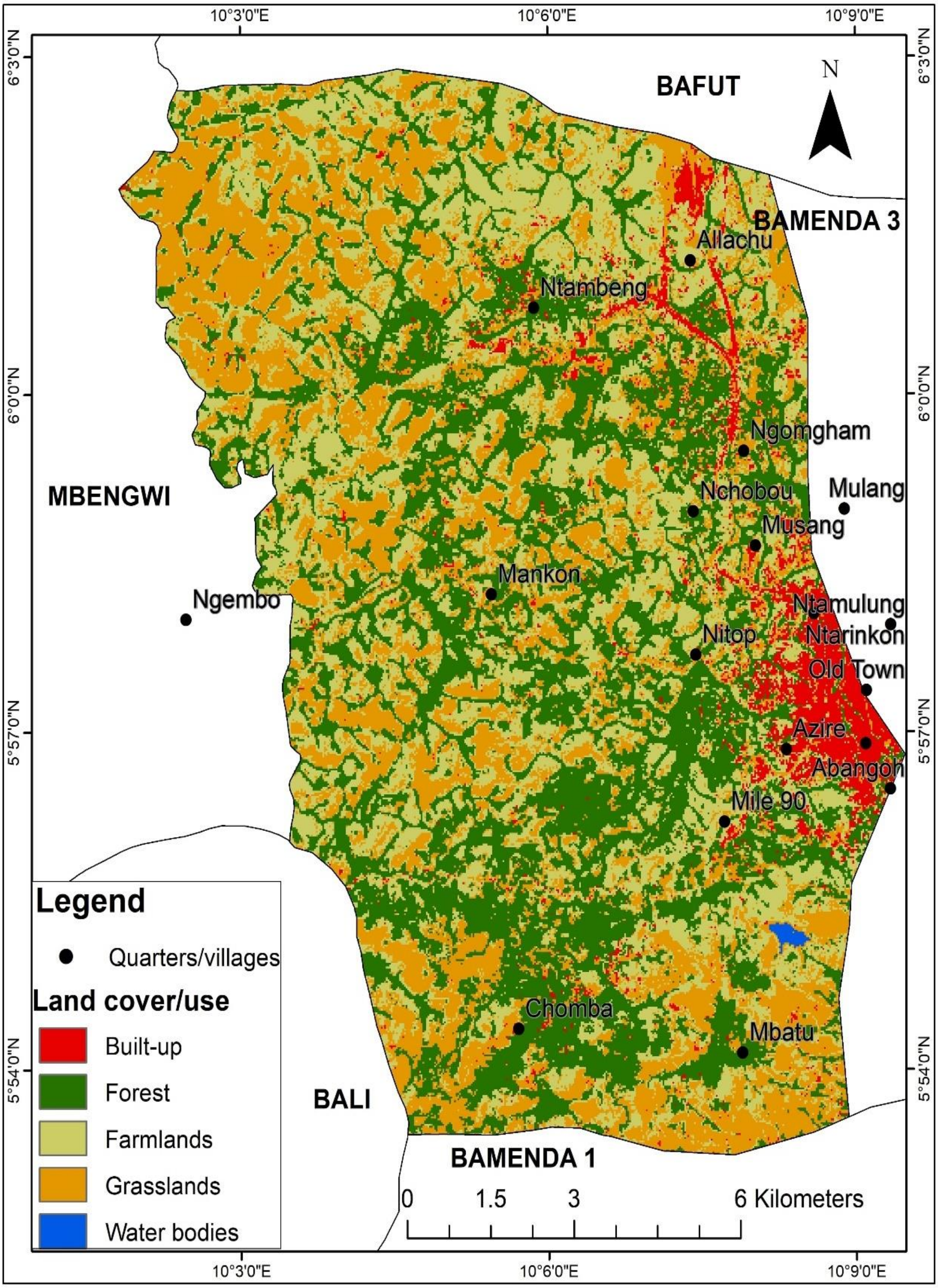
Source: Landsat 5, 6, 7, 8 of USGS, TM, ETM+, OLI/TIRS,

In 1984, built-up area was 830.07 ha, farmlands (5,304.24 ha), grassland (5,224.91 ha), forest (5,813.91 ha) and water bodies (17.19 ha) (Figure 3.11).

By 2003, built-up area had increased to 1,386 ha, while farmlands increased to 6,488.64 ha. Grassland rather reduced to 4,387.59 ha, and water bodies reduced to 15.57 ha (Figure 3.12).

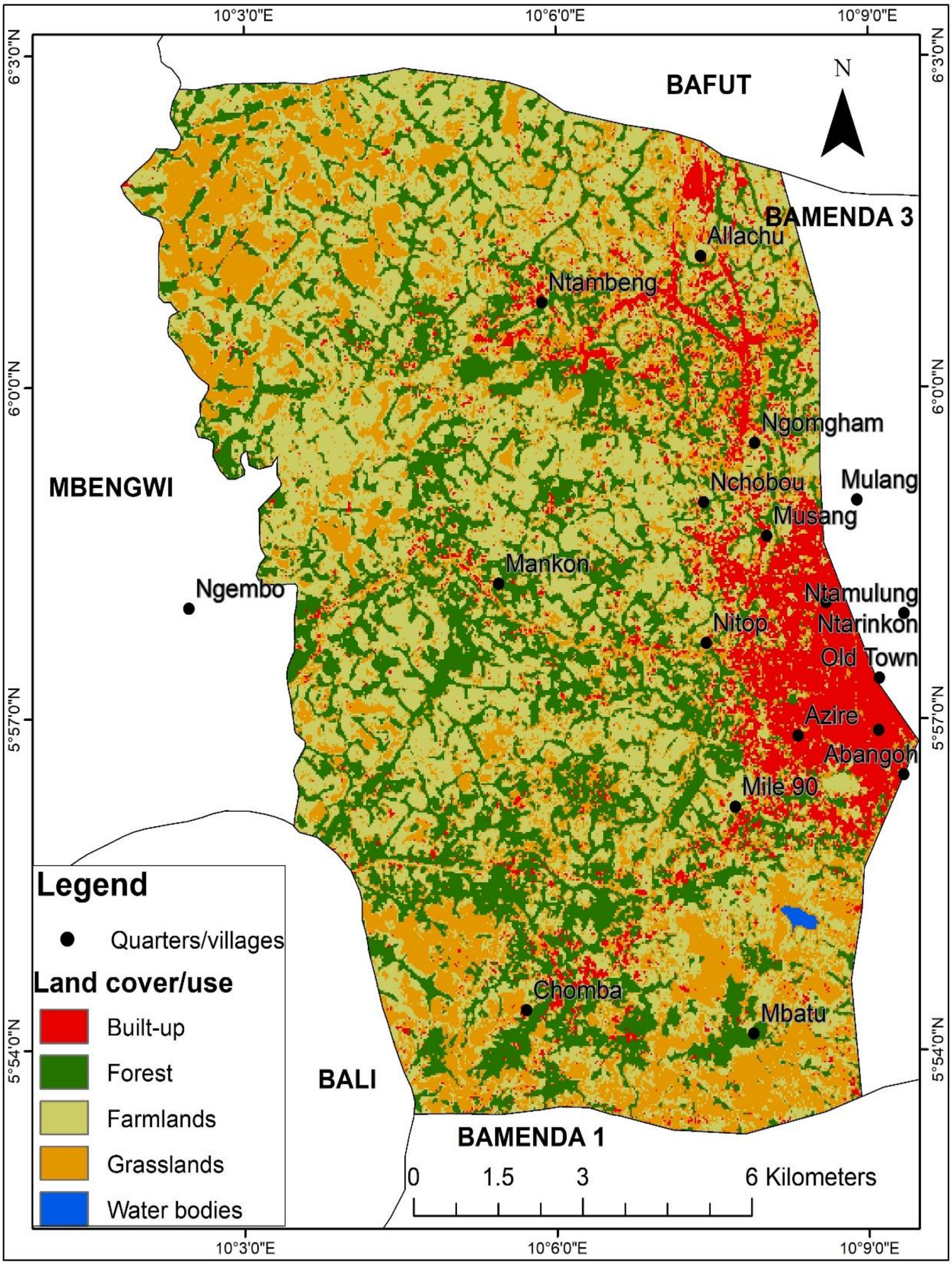
Furthermore, in 2013, built-up area had grown to 2,551.59 ha, to detriment of farmlands (4,608.09 ha), grassland (1,559.7 ha), forest (8,447.13 ha) and water bodies (22.95 ha) (Figure 3.13).

Finally, by 2022, built-up area had increased to 3027.15 ha, to detriment of farmlands (5,165.28 ha), grassland (2,741.31 ha), forest (6,237 ha) and water bodies (18.72 ha) (Figure 53.14).



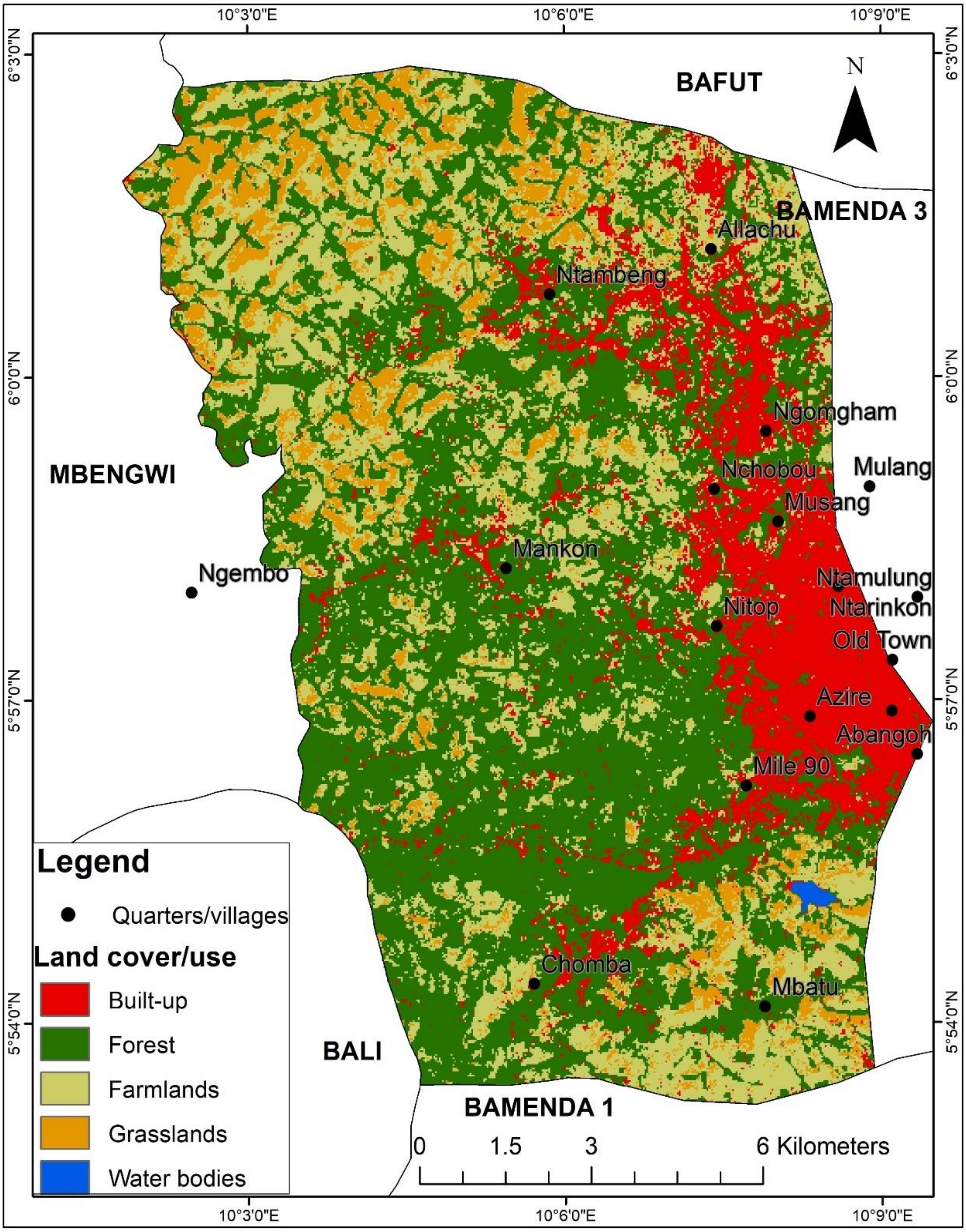
Source: USGS, 1984

Figure3. 11: Land cover/use in Bamenda II (1984)



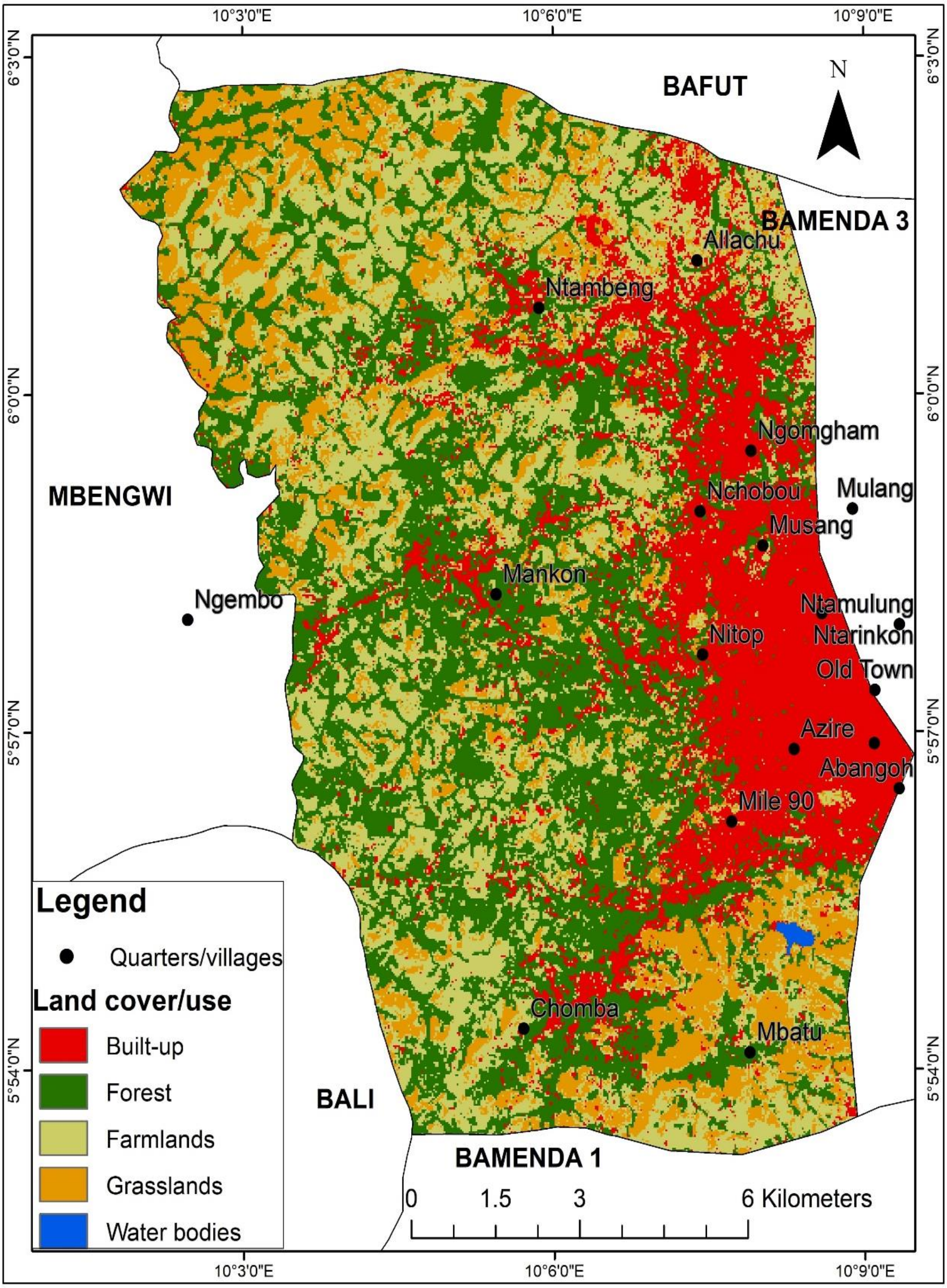
Source: USGS, 2003

Figure3. 12: Land cover/use in Bamenda II (2003)



Source: USGS, 2013

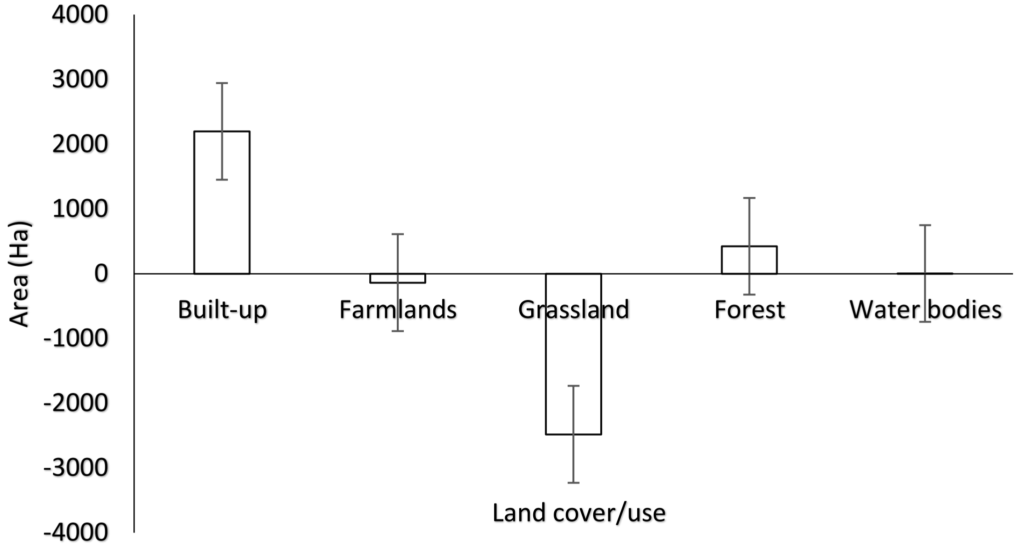
Figure3. 13: Land cover/use in Bamenda II (2013)



Source: USGS, 2022

Figure3. 14: Land cover/use in Bamenda II (2022)s

Summarily, built-up areas have taken up much space than other land covers in Bamenda II over the period under study (Figure 3.15). The most affected land covers have been grassland and farmlands, as they have been taken over by human settlements (urbanization).



Source: Table 5.4

Figure 3. 15: Relative land use/cover in Bamenda II from 1984-2022

This has negative ramifications on crop production as urbanization and agricultural land are not compatible (Figure 3.16).

Plate 3. 1: Evidence of land use competition between human settlements and agriculture in Bamenda II

It has been observed that land is highly competitive between human settlements and agriculture in Bamenda II. Houses have been constructed on steeper slopes and reclaimed wetlands that could be more appropriate for agriculture.

3.5 Statistical Evaluation of adaptation strategies by farmers in Bamenda II

The hypothesis for this chapter stated that adaptation measures implemented by farmers in Bamenda have significantly reduced maize farmer's vulnerability to climate variability and increase food production. This hypothesis was verified using the analysis of variance (ANOVA) (Table 3.8).

Table 3.8: Linear Regression for adaptation strategies for maize production in Bamenda II

ANOVA[a]					
Model	Sum of Squares	df	Mean Square	F	Sig.
Regression	165.249	5	33.050	6.250	.000[b]
Residual	.000	247	.000		
Total	165.249	252			
a. Dependent Variable: Maize yields, b. Predictors: (Constant), New technologies, Improved seeds, Changing planting dates, Planting trees, Irrigation schemes					

The interactive frequency for adaptation measures implemented by farmers in Bamenda and its implication on maize farmer's vulnerability to climate variability and increase food production is 6.25 with 5 and 247 degree of freedom (df) in which p-value is 0. Since the p-value is 0, we therefore reject the hypothesis.

3.6 Conclusion

Adaption to climate variability to ensure food security takes into indigenous and conventional strategies. In Bamenda II, farmers employ agro-forestry, micro-irrigation schemes (dry season), indigenous soil and water conservation, alteration of planting dates, as well as use of improved planting materials. The success of these strategies is possible with sustainable livelihood assets. The social, natural and human capital assets are available, but financial and physical capital assets are scare. These acts as constraints to adaptation to climate variability to ensure food security.

DISCUSSION OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

Discussion of Findings

Rainfall characteristics and trend

The first objective of this study was to appraise the characteristics and trend of climate variability in the Bamenda II Municipality. Farmers perceived that temperature has been rising against a backdrop of declining rainfall trends (high magnitude of climate variability). Weather and climate records show variability on every time-scale, from daily, seasonal and annual to over hundreds or even thousands of years. The rise in global temperature also affects other climate variables. Higher temperatures may result in more precipitation falling as rain (Organisation for Economic Co-operation and Development-OECD, 2009). Although increasing global temperatures result in increased global precipitation, the increase is not spread evenly (Tume and Fogwe, 2019). In general, the tropics and sub-tropical areas experience a decrease in precipitation (IPCC, 2007). There are likely to be substantial variations in changes in precipitation patterns within these latitudinal ranges (Tume and Nyuyfoni, 2021). The seasonality of precipitation patterns is also likely to change in many locations in the tropics (Tume, 2022).

While changes in average weather conditions are important, societies, particularly in developing countries are more vulnerable to extreme conditions, such as floods and droughts (meteorological, hydrological and agricultural) (Christensen et al., 2013). Climate variability is also causing changes in these weather extremes, which can have much more significant consequences on society than average increases in temperature (Omambia et al., 2010). There is now a growing consensus that climate change is likely to result in more frequent, heavy precipitation events and droughts (Tume, 2022).

Mean annual rainfall over Cameroon has decreased by about 2.9 mm per month (2.2%) per decade since 1960 (McSweeney et al., 2006). Cameroon experienced particularly low rainfall in 2003 and 2005. There is insufficient daily precipitation data available to determine trends in daily rainfall extremes. Mean annual temperature on the other hand has increased by 0.7^{o}C since 1960, an average rate of 0.15^{o}C per decade (Ngakfumbe, 2001). The rate of increase over the whole country is most rapid at 0.19^{o}C per decade, but in the north of Cameroon, the warming is most rapid in December, January, February and September, October, November, occurring at rates of 0.2 to 0.4^{o}C per decade (McSweeney et al., 2006). There are few daily observations available from which to infer changes in daily temperature extremes. The average number of 'hot' nights per year in Cameroon has increased by 79 (additional 21.7% of nights) between 1960 and 2003.

Impact of climate variability

The second specific objective of this study evaluated the impact of climate variability on maize production and food security in the Bamenda II Municipality. Climate variability and change affects the ability of rural communities to satisfy those needs that are inherent to the environment (International Labour Organization-ILO, 2017). Even though changes have been occurring over generations, rural farmers have been adapting to these changes throughout their life using local environmental knowledge (Gyampoh et al., 2009). The knowledge is relatively cheap, readily available to rural farmers and it is a climatically smart tool for sustainable development and the management of climate variability (Abeysinghe, 2013). Environmental problems vary spatio-temporarily (Krishna, 2011), but rural farmers, through continued experimentation, trial and error and sustained interactions with their local environment, have developed a vast local knowledge about nature in their locale that they use in coping with and solving their problems, amongst which are climate-related problems (Beckford and Barker, 2007).

The effects of climate variability and change on crop and terrestrial food production are evident in several regions of the world (Elum et al., 2017). Negative impacts of climate trends have been more common than positive ones (Porter et al., 2014). All aspects of food security are potentially affected by climate change, including food access, utilization and price stability (Tume et al., 2020). For a major crop like maize in the tropics, climate change without adaptation will negatively impact production for local temperature increases of 2°C. Temperature trends are important for determining both past and future impacts of climate change on crop yields at sub-continental to global scales (OECD, 2009). At scales of individual countries, precipitation projections remain important but uncertain factors for assessing future impacts. Changes in temperature and precipitation, without considering effects of CO_2, will contribute to increased global food prices by 2050, with estimated increases ranging from 3 to 84%. Projected impacts vary across crops and regions and adaptation scenarios, with about 10% of projections for the period 2030–2049 showing yield gains of more than 10% and about 10% of projections showing yield losses of more than 25% in Africa (OECD, 2009).

Increasing temperatures and declining rainfall patterns as well as increasing frequency of extreme climate events such as droughts and floods are the expected future weather patterns within the tropics (Mathews et al., 2016). Africa is projected to be the region most vulnerable to the impacts of climate variability and change. This has dire consequences as most people depend on agriculture for their livelihoods. The impacts of climate change and variability are felt locally at household, community, national and regional levels. In most cases adaptation occurs at local level in ways that are usually unnoticed and unaided by national governments and international organisations. Down-scaling the vulnerability climate change and variability to household and community levels is a pre-emptive action to designing indigenous adaptation strategies (Mulwa et al., 2017).

Adaptive strategies in the face of climate variability

The third specific objective examined stakeholder adaptive strategies formaize production to ensure food security. An outstanding outcome of the 21st session of the UNFCCC Conference of Parties (COP-21) was the spelling of adaptation measures. In the implementation of nationally determined agenda in the context of sustainable development and poverty eradication, countries must include amongst other things, climate mitigation and adaptation (Sharmais et al., 2016). These measures must be sustained through improving the effectiveness and durability of adaptation actions, implementation of adaptation actions, undertakings, efforts, formulate and implement national adaptation plans, assessment of climate change impacts and vulnerability (Tume and Maghah, 2021; Tume and Kimengsi, 2021). This is done with a view to formulating nationally determined prioritized actions, considering vulnerable people, places and ecosystems, monitoring, evaluating and learning from adaptation plans, policies, programs and actions, building the resilience of socio-economic and ecological systems, including economic diversification and sustainable management of natural resources (Bertram et al., 2017).

In Cameroon, a regional Climate Change Observatory, ONACC (Observatoire National sur les Changements Climatiques), has already been recommended by Government (UNDP, 2009). In the context of the Africa Adaptation Program (AAP), ONACC is charged with coordinating the implementation of research and information generation aspects of climate change vulnerability and adaptation. The AAP will provide support to establish the ONACC as adaptation capacity. Climate change risks will be identified and realized by a variety of sectors (agriculture, water, fisheries, health, environment, infrastructure, energy). Responsive adaptive planning capacities will be built. ONACC as a Cameroonian institution with regional outreach will be strengthened as local climate change centre of excellence for research, policy advice, capacity building and information sharing, thus building national and local adaptive capacities.

Adaptation reduces the impacts of climate stresses on human and natural systems (Levina and Tirpak, 2006). It consists of a multitude of behavioral, structural and technological adjustments. Adaptation measures can vary in:

- Timing (anticipatory vs reactive; ex-ante vs ex-post)
- Scope (short-term vs long-term; localised vs regional)
- Purposefulness (autonomous vs planned; passive vs active)
- Adapting agent (private vs public; societies vs natural systems).

Examples of adaptation measures include changing crop varieties and altering farming practices, developing heat and drought-resistant crops, diversifying livelihoods, building flood defenses and land-use planning. Nevertheless, the need to adapt to changing environmental and climatic conditions is not a new one. Societies throughout history have adapted to variations or changes in their climate through a variety of strategies and by using knowledge accumulated through experience of past climatic events (IIED, 2015 a, b). In addition, societies have also had to cope with and respond to extreme weather events, such as droughts and floods (Mathews et al., 2016). For example, the tropics have historically frequently faced extreme climatic variability and events such as droughts. Societies in the tropics have, therefore, must regularly adapt to unreliable rainfall and drought conditions for example by diversifying their livelihoods and adopting new crop varieties (OECD, 2009).

Conclusion

The first specific objective of this study was to appraise the characteristic and trend of climate variability in Bamenda II. The population of Bamenda II Sub-division perceives that the magnitude of climate variability is high (46.2%). The dependable sources of climate information are radio and television with values of 41.5% and 33.3% respectively. Recent changes in climatic dynamics include increasing temperatures, oscillations in the onset of the first rains and cessation of the wet season, increasing incidence of wind on agriculture, human settlements and urban infrastructure. Meteorological data indicates that the inter-annual rainfall trend is decreasing, while the inter-annual temperature is increasing. Again, the trend of the growing season has been evaluated using the Cumulative Departure Index (CDI), showing a decreasing trend. Rainfall reliability (Coefficient of Variation-CV) shows that the trend has increased from 10.69% in the decade 1963-1972 (reliable) to 25.91% during the period 2013-2021 (unreliable). The CV is complemented by the Standardized Precipitation Index (SPI), which shows a decreasing trend with recurrent meteorological, hydrological and agricultural droughts. These culminate with a decreasing number of rainy days, leading to food and water insecurity.

The second specific objective was to examine the impacts of climate variability on maize production and food security in Bamenda II. Agriculture is very important to the economy of Cameroon at large and should be improving upon so as to enhance food security. So many parts of the world today especially those in the developing countries is hit by food insecurity which is mainly due to the constraints affecting the smooth functioning of the agricultural sector. Reduction in hunger is driven by projected socioeconomic development. Most agricultural practices especially in Africa depends on rained agriculture for their livelihoods, therefore the tendency of food insecurity may likely be upward projection. There is therefore serious need to protect the environment against human activities that affect the rainfall pattern especially those activities contributing to climate variability. The understanding of the relationship between climate and agriculture will enable agriculturalists or farmers to fit crops to climate and avoid unpleasant consequences of agricultural planning and development.

The third specific objective was to evaluate the existing climate variability adaptation strategies practiced by farmers to fight against food insecurity in Bamenda II. Adaption to climate variability to ensure food security takes into indigenous and conventional strategies. In Bamenda II, farmers employ agro-forestry, micro-irrigation schemes (dry season), indigenous soil and water conservation, alteration of planting dates, as well as use of improved planting materials. The success of these strategies is possible with sustainable livelihood assets. The social, natural and human capital assets are available, but financial and physical capital assets are scare. These acts as constraints to adaptation to climate variability to ensure food security.

Recommendations

Stakeholders involved in enhancing farmers' adaptation strategies on food crop production should be followed up by the appropriate authorities such as the Delegates of Agriculture and Rural Development to ensure success. NGOs should not limit their intervention only on sensitization but also make sure that they give support to farmers in terms of crop species and fertilizers and farmers should be treated the same without favoring some farmers more than others. Farmers should be sensitized on the existence of government programs that are aimed at improving farmers' yields and technical know-how of the farmers such as ACEFA which is not known by many farmers. Some NGOs have also been doing much to support rural farmers to improve on their agricultural output. Most of their activities include subsidised fertilizers, training and capacity building for sustainable agriculture and environmental conservation.

Farmers in Bamenda II need rapid results and are more inclined to adopt short-term adaptation practices. Any promotion of conservation type of agriculture to build long-term resilience of farmers or contribute to the mitigation of climate change will require complementary incentives to partly cover the costs of the investment or help farmers recover part of the opportunity cost of the land before the investments begins to yield results. Although farmers are aware of changing environment and its impact on their livelihoods, they need to be constantly informed and educated about the causes of the increasing environmental challenges. Such education could be through the regular extension systems, but it also requires more intensive and extensive awareness creation campaigns.

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APPENDIX 1: QUESTIONNAIRE

Dear Respondent,

I am Akombo Blaise Fru, a student of the Department of Geography, University of Yaounde I, carrying out research on ‘Climate Variability Impacts on Maize Production and Urban Food Security in Bamenda II Sub-division’. I will be grateful if you kindly provide answers to these questions as they will help in the accomplishment this task. The information you provide will be used strictly for academic purposes. Please kindly tick (✓) where necessary.

Section A: Identification of Respondents

CODES	Identification	Options
ID_1	Sex	▢Male(1), ▢Female(2)
ID_2	Marital status	▢Single(1), ▢Married(2), ▢Widowed(3), ▢Divorced(4)
ID_3	Age group	▢<25(1), ▢26-34(2), ▢36-45(3), ▢46-55(4), ▢55+(5)
ID_4	Family size	▢1-3(1), ▢4-6(2), ▢7-9(3), ▢10^+(4)
ID_5	Educational level	▢No formal education(1), ▢FSLC(2), ▢GCE O/L(3), ▢GCE A/L(4), ▢University(5)
ID_6	Quarter/Village	▢Chomba(1), ▢Nsongwa(2), ▢Mbatu(3), ▢Mulang(4), ▢Ntangkah(5), ▢Mukwebuh(6)
ID_7	Occupation	▢Farming(1), ▢Business(2), ▢Teacher(3), ▢Student(4), ▢Bike rider(5), ▢Driver(6), ▢Technician(7), ▢Health personnel(8)

Section B: Climate variability

1. Climate Variability

CODES	Questions	Options
CV_1	Have you witnessed any changes in the climate of Bamenda II?	▢Yes (1), ▢No(2), ▢Don’t know(3)
CV_2	How can you rate the magnitude of changing climatic conditions of your locality?	▢High(1), ▢Low(2), ▢Medium(3), ▢Don’t know(4)
CV_3	Sources of climate change	▢Television(1), ▢Radio(2), ▢Government

	information	agencies(3), ▢Internet(4), ▢NGOs(5), ▢Quarter meeting (6)

2. What are some of the recent changes as compared to the past?

CODES	Variability over time	SA	A	N	SD	D
CV_4	Increase in temperature					
CV_5	Longer rainy season					
CV_6	Increase in incidence of wind					
CV_7	Decrease in rainfall					
CV_8	Increase in sunshine					
CV_9	Longer dry season					

SA: Strongly, A: Agree, Neutral: N, Strongly Disagree: SD, D: Disagree

3. Given the variability in climate, which periods witnessed a greater change in temperature and rainfall?

CODES	Period	Magnitude
Temperature		
CV_10	1980-1990	▢High(1), ▢Low(2), ▢Medium(3), ▢Don't know(4)
CV_11	1991-2001	▢High(1), ▢Low(2), ▢Medium(3), ▢Don't know(4)
CV_12	2001-2011	▢High(1), ▢Low(2), ▢Medium(3), ▢Don't know(4)
CV_13	2011-2021	▢High(1), ▢Low(2), ▢Medium(3), ▢Don't know(4)
Rainfall		
CV_14	1980- 1990	▢High(1), ▢Low(2), ▢Medium(3), ▢Don't know(4)
CV_15	1991-2001	▢High(1), ▢Low(2), ▢Medium(3), ▢Don't know(4)
CV_16	2001-2011	▢High(1), ▢Low(2), ▢Medium(3), ▢Don't know(4)
CV_17	2011-2021	▢High(1), ▢Low(2), ▢Medium(3), ▢Don't know(4)

4. Causes and effects of climate variability

a) What can be the cause of this variability in Bamenda II?

CODES	Causes	High (1)	Medium (2)	Low (3)
CE_1	Agriculture			
CE_2	Deforestation			

CE_3	Population increase			
CE_4	Poor waste disposal			
CE_5	Wetland reclamation			
CE_6	Urban growth			

b) How does climate variability affect your community?

CODES	Effects	Yes (1)	No (2)	Don't know (3)
CVA_1	Low yields			
CVA_2	Floods			
CVA_3	Soil erosion			
CVA_4	Agro-meteorological droughts			
CVA_5	Variation in dry and wet season			

Section C: Effects on Climate Variability on Maize Production and Food Security

5. Effects on Climate Variability on Maize Production and Food Security

CODES	Questions	Options
EFFECT_1	Which type of agricultural practice do you engage in?	☐Mixed cropping(1), ☐Market gardening(2), ☐Mono cropping(3), ☐Intensive farming(4), ☐Extensive farming(5), ☐Non(6), ☐All(7)
EFFECT_2	What are the effects of climate variability on the farming methods	☐Drop in crop yields(1), ☐Increase in soil erosion(2), ☐Increase in soil nutrients(3), ☐All effects(4)
EFFECT_3	Which of these conditions is regular?	☐Onset of first rains(1), ☐Cessation of rains(2), ☐Both(3)
EFFECT_4	How does the late onset of rains affect the agricultural calendar?	☐Late planting(1), ☐Poor yields(2), ☐Wilting of crops(3), ☐All effects(4)

6. Availability of food in your community

No	Options	Yes	No
AVAIL_1	Is food enough for your household every day		
AVAIL_2	Has the produce been the same for the past years		
AVAIL_3	Has the prices of food crops been fluctuating in the community market recently		
AVAIL_4	Has rainfall been reliable for crop production		
AVAIL_5	Is the 'Ankara' system of farming advisable in the face of climate change		

7. Assess the dimensions of food security in your community?

CODES	Dimensions	Increase (1)	Decrease (2)	No change (3)
DIMEN_1	Food availability			
DIMEN_2	Food accessibility			
DIMEN_3	Food utilization			
DIMEN_4	Food stability			

8. Perceived changes in maize yields

CODES	Maize varieties	Increase (1)	Decrease (2)	No change (3)
PCMY_1	ATP			
PCMY_2	PANNAR			
PCMY_3	Coca			
PCMY_4	White maize			
PCMY_5	Others			

9. Problems encountered in maize production

CODES	Problems	Yes (1)	No (2)
PROB_1	Inadequate credit facilities		
PROB_2	Seasonal variation		
PROB_3	Fluctuation in market price		
PROB_4	Pest and disease		
PROB_5	Inadequate storage facilities		
PROB_6	Poor transport facilities		

10. CONS_0: How often do you consume corn-related products? ▢One a week(1),▢Twice a week(2), ▢Four times a week(3), ▢Five times a week(4), ▢Everyday(5), ▢Once in a while(6)

10. Assess the consumption of the following corn products in your household:

CODES	Products	Frequently (1)	Once in a while (2)	Never (3)
CCP_1	Corn pap			
CCP_2	Fufu corn			
CCP_3	Corn chaff			
CCP_4	Boiled corn			
CCP_5	Fried corn			
CCP_6	Roasted corn			
CCP_7	Koki corn			
CCP_8	Corn drinks			

Household Food Insecurity Access Scale

11. What are your sources of food?

CODES	Source	No (1)	Yes (2)	Not Applicable (3)
HFIAS_1	Own crop production			
HFIAS_2	Barter			
HFIAS_3	Own livestock products			
HFIAS_4	Purchase			
HFIAS_5	Wild food collection			
HFIAS_6	Exchange labour for food			
HFIAS_7	Hunting			
HFIAS_8	Steal			
HFIAS_9	Friends/relatives			
HFIAS_10	Food at school			
HFIAS_11	Food at work			
HFIAS_12	Other food sources			

12. How do you rate the level of access to food today as compared to five years ago?

CODES	HFIAS_13a	HFIAS_13b	HFIAS_13c	HFIAS_13d
Rate	No change (1)	Better (2)	Fair (3)	Worse off (4)
Tick (✓)				

13. If the situation is fair or worse off, what might have contributed?

CODES	Options	Scaling					
		<5%	6-10%	11-15%	16-20%	21-25%	26%+
HFIAS_14	Income not increasing at the rate of inflation						
HFIAS_15	Poor harvest due to drought						
HFIAS_16	Poor harvest due to low temperatures						
HFIAS_17	Poor harvest due to pests and diseases						
HFIAS_18	Lack of agricultural inputs						
HFIAS_19	Poor salaries						
HFIAS_20	Retirement						
HFIAS_21	Retrenchment						
HFIAS_22	Reduced government support						
HFIAS_23	Increased household size						
HFIAS_24	Death of the main food provider						
HFIAS_25	Other (specify)						

14. How often did the following happen? 1 = rarely (once or twice in the past month), 2 = Sometimes (three to ten times in the past), 3 = Often (more than ten times in the past month)

CODES	Questions	Rarely	Sometimes	Often
HFIAS_26	Did you worry that your household would not have enough food?			
HFIAS_27	Was your household not able to eat the kinds of			

	foods you preferred because of lack of resources?			
HFIAS_28	Did you or any household member have to eat a limited variety of foods due to lack of resources?			
HFIAS_29	Did you or any household member have to eat some foods you really did not want because of lack of resources to obtain other types of food?			
HFIAS_30	Did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food?			
HFIAS_31	Did you or any household member have to eat fewer meals in a day because there was not enough food?			
HFIAS_32	Was there ever no food to eat of any kind in your household because of lack of resources to get food?			
HFIAS_33	Did you or any household member go to sleep at night hungry because there was not enough food?			
HFIAS_34	Did you or any household member go a whole day and night without eating because there was not enough food?			

15. When do any of the above problems happen?

CODES	HFIAS_35a	HFIAS_35b	HFIAS_35c	HFIAS_35d	HFIAS_35e
Period	Anytime of the year	Just before month end	Before harvesting	After drought	Any time of the year
✓					

16. What adjustments or possible solutions have you made to avoid food shortages if any or to improve your diet?

CODES	Options	SA	A	SD	D	N
ADJUST_1	Food grants					
ADJUST_2	Borrow money from friends or relatives					
ADJUST_3	Dispose household assets					

ADJUST_4	Reduction in non-food household expenditure					
ADJUST_5	Reduce the number of meals per day					
ADJUST_6	Resort to external relationships tom secure food					
ADJUST_7	Change area of residence					
ADJUST_8	Petty trading					
ADJUST_9	Sale of livestock					
ADJUST_10	Get loans from money lenders or credit union					
ADJUST_11	Reduce the amount of food					
ADJUST_12	Did not pay credits already owed					
ADJUST_13	Over-use of natural resources					
ADJUST_14	Other adjustment mechanisms					

17. On average, what percentage of your income did you spend on food?

CODES	INCOME_1	INCOME_2	INCOME_3	INCOME_4
Period	Last month end	Last year	Past five years	Past 10 years
Tick one per group (✓)	▢5-10% ▢11-20% ▢21%+ ▢Don’t know	▢5-10% ▢11-20% ▢21%+ ▢Don’t know	▢5-10% ▢11-20% ▢21%+ ▢Don’t know	▢5-10% ▢11-20% ▢21%+ ▢Don’t know)

18. What might have contributed to the changes?

CODES	CONTRI_1	CONTRI_2	CONTRI_3	CONTRI_4
Changes	Food price increase (1)	Poor harvests (2)	Low income (3)	High income (4)
Tick (✓)				

19. What agricultural activities have you practice over the past 10 years+?

CODES	ACT_1	ACT_2	ACT_3	ACT_4	ACT_5
Activities	Livestock	Field crops	Poultry	Other (specify)	None
Tick (✓)					

Section D: Adaptation to climate variability

20. What are the adaptation measures you use to cope with the effect of climate variability on agriculture?

CODES	Adaption measures	Yes (1)	No (2)	Don’t know (3)
ADAPT_1	Planting trees			
ADAPT_2	Irrigation schemes			
ADAPT_3	Soil and water conservation			
ADAPT_4	Changing planting date			
ADAPT_5	Improved seeds			
ADAPT_6	New technologies			
ADAPT_7	Others			

21. What are the major barriers you encounter to implement adaptation strategies?

CODES	Challenges	Yes (1)	No (2)	Don’t know (3)
BARRIER_1	Lack of information about long-term climate change			
BARRIER_2	Inadequate knowledge on adaptation			
BARRIER_3	Insufficient credit services			
BARRIER_4	Inaccessibility to water points for irrigation			

22. Assess the Sustainable Livelihoods Assets in your community for climate adaptation?

CODE	Assets	Yes (1)	No (2)	Don’t know (3)
Social Capital and Climate Variability and Climate Adaptation				
SLA_1	Membership of a cooperative			
SLA_2	Membership of a njangi group			
SLA_3	Member of CIG			
Natural Capital and Climate Variability and Change Adaptation				
SLA_4	Streams or water reservoirs have been drying in the previous years			
SLA_5	Enough land to grow crops, keep livestock and road networks to access market opportunities			

Financial Capital and Climate Variability and Change Adaptation				
SLA_6	Availability of grants, loans and credit available to rural farmers			
SLA_7	Pension money and social grants are sufficient to offset food insecurity and the impact of climate change			
SLA_8	Enough credit and funding for our farming endeavors			
Physical Capital and Climate Variability and Change Adaptation				
SLA_9	Enough tractors and essential mechanization for crop farming			
SLA_10	Size of the land is too small, and the quality of the soil is poor for farming			
Human Capital and Climate Variability and Change Adaptation				
SLA_11	More education to better understand and mitigate the impact of climate variability on food security			
SLA_12	Capacity and skills to work on the lands, youth engagement			
SLA_13	Women are majority of farmers			

APPENDIX 2: CALCULATION OF RAINFALL CHARACTERISTICS AND TRENDS

Years	Mean rainfall (mm)	Deviation from the mean	SPI	Category
1951	223.48	37.78	1.21	Moderately wet
1952	224.20	38.49	1.23	Moderately wet
1953	198.52	12.81	0.41	Mildly wet
1954	251.31	65.60	2.10	Extreme wet
1955	213.05	27.34	0.88	Mildly wet
1956	194.80	9.09	0.29	Mildly wet
1957	250.48	64.77	2.07	Extreme wet
1958	210.13	24.42	0.78	Mildly wet
1959	202.52	16.81	0.54	Mildly wet
1960	183.75	-1.96	-0.06	Mild dryness
Mean	215.22	29.52	0.94	

SD	22.54	CV	10.47	
1961	201.08	15.37	0.49	Mildly wet
1962	169.91	-15.80	-0.51	Mild dryness
1963	228.36	42.65	1.37	Moderately wet
1964	215.18	29.48	0.94	Mildly wet
1965	203.68	17.98	0.58	Mildly wet
1966	214.37	28.66	0.92	Mildly wet
1967	210.62	24.91	0.80	Mildly wet
1968	217.83	32.12	1.03	Moderately wet
1969	241.33	55.63	1.78	Moderately wet
1970	214.25	28.55	0.91	Mildly wet
Mean	211.66	25.95	0.83	
SD	18.69	CV	8.83	
1971	164.90	-20.81	-0.67	Mild dryness
1972	178.63	-7.07	-0.23	Mild dryness
1973	162.31	-23.40	-0.75	Mild dryness
1974	191.95	6.24	0.20	Mildly wet
1975	183.76	-1.95	-0.06	Mild dryness
1976	196.00	10.29	0.33	Mildly wet
1977	184.15	-1.56	-0.05	Mild dryness
1978	204.50	18.79	0.60	Mildly wet
1979	226.53	40.82	1.31	Moderately wet
1980	207.48	21.77	0.70	Mildly wet
Mean	190.02	4.31	0.14	Mildly wet
SD	19.69	CV	10.36	
1981	207.09	21.39	0.68	Mildly wet
1982	197.24	11.54	0.37	Mildly wet
1983	182.23	-3.47	-0.11	Mild dryness
1984	192.11	6.40	0.20	Mildly wet
1985	189.58	3.88	0.12	Mildly wet
1986	190.02	4.31	0.14	Mildly wet
1987	164.10	-21.61	-0.69	Mild dryness

1988	171.03	-14.67	-0.47	Mild dryness
1989	195.56	9.85	0.32	Mildly wet
1990	190.39	4.69	0.15	Mildly wet
Mean	187.94	2.23	0.07	
SD	12.60	CV	6.70	
1991	182.65	-3.06	-0.10	Mild dryness
1992	197.50	11.79	0.38	Mildly wet
1993	210.18	24.47	0.78	Mildly wet
1994	181.77	-3.94	-0.13	Mild dryness
1995	185.21	-0.50	-0.02	Mild dryness
1996	179.58	-6.13	-0.20	Mild dryness
1997	179.69	-6.01	-0.19	Mild dryness
1998	178.32	-7.39	-0.24	Mild dryness
1999	194.31	8.60	0.28	Mildly wet
2000	182.30	-3.41	-0.11	Mild dryness
Mean	187.15	1.44	0.05	
SD	10.31	CV	5.51	
2001	153.74	-31.96	-1.02	Moderate dryness
2002	169.99	-15.71	-0.50	Mild dryness
2003	174.96	-10.75	-0.34	Mild dryness
2004	188.77	3.06	0.10	Mildly wet
2005	182.20	-3.51	-0.11	Mild dryness
2006	206.43	20.73	0.66	Mildly wet
2007	142.36	-43.35	-1.39	Moderate dryness
2008	131.59	-54.11	-1.73	Severe dryness
2009	153.07	-32.64	-1.04	Moderate dryness
2010	167.97	-17.74	-0.57	Mild dryness
Mean	167.11	-18.60	-0.60	
SD	22.52	CV	13.48	
2011	186.56	0.85	0.03	Mildly wet
2012	162.31	-23.40	-0.75	Mild dryness
2013	228.36	42.65	1.37	Moderately wet

2014	122.61	-63.10	-2.02	Extreme dryness
2015	140.10	-45.61	-1.46	Moderate dryness
2016	99.25	-86.46	-2.77	Extreme dryness
2017	123.23	-62.47	-2.00	Moderate dryness
2018	136.53	-49.17	-1.57	Severe dryness
2019	136.92	-48.79	-1.56	Severe dryness
2020	129.84	-55.86	-1.79	Severe dryness
2021	128.49	-57.21	-1.83	Severe dryness
Mean	144.93	-40.78	-1.31	Moderate dryness
SD	35.65	CV	24.60	

APPENDIX 3: CALCULATION OF TEMPERATURE TRENDS

Years	Mean Temperature (°C)	Years	Mean Temperature (°C)
1971	18.37	1997	20.02
1972	18.50	1998	19.89
1973	19.14	1999	19.68
1974	18.43	2000	20.60
1975	18.48	Mean	18.85
1976	18.32	2001	19.45
1977	18.71	2002	20.02
1978	18.89	2003	19.72
1979	19.05	2004	20.55
1980	18.87	2005	20.60
Mean	18.68	2006	22.19
1981	18.79	2007	21.91
1982	18.69	2008	21.62
1983	18.75	2009	22.05
1984	18.41	2010	22.09
1985	18.78	Mean	21.02
1986	18.58	2011	21.61
1987	17.90	2012	21.63
1988	18.53	2013	21.71
1989	18.38	2014	21.90
1990	18.78	2015	21.83
Mean	18.56	2016	22.04
1991	18.67	2017	22.06
1992	18.43	2018	21.89
1993	18.95	2019	22.19
1994	18.64	2020	23.05
1995	19.38	2021	24.60
1996	19.55	Mean	22.23