VULNERABILITY ATTENUATION AND RESILIENCE ENHANCEMENT TO CLIMATE VARIABILITY AND CHANGE THROUGH AGROFORESTRY PRACTICES IN SMALLHOLDER FARMING SYSTEMS IN THE NORTH-WEST REGION OF CAMEROON

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VULNERABILITY ATTENUATION AND RESILIENCE ENHANCEMENT TO CLIMATE VARIABILITY AND CHANGE THROUGH AGROFORESTRY PRACTICES IN SMALLHOLDER FARMING SYSTEMS IN THE NORTH-WEST REGION OF CAMEROON

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CERTIFICATION

This is to certify that this PhD thesis titled **"Vulnerability Attenuation and Resilience Enhancement to Climate Variability and Change through Agroforestry Practices in Smallholder Farming Systems in the North-West Region of Cameroon"** submitted through the Department of Forestry to the Dschang School of Agriculture and Environmental Sciences (DSAES), Faculty of Agronomy and Agricultural Sciences, University of Dschang as part of the requirements for the award of the degree of PhD in Agroforestry and valuation of ecosystem services, is an original and an innovative piece of work undertaken by **NYONG Princely AWAZI, registration number CM-UDS-13ASA0600,** under the mentorship of **Prof. TCHAMBA NGANKAM Martin** and **Dr. TEMGOUA Lucie Félicité.** As supervisors of this scientific work, we duly acknowledge to the best of our knowledge that the contents found therein have not been submitted in any form to another university for the award of any degree or diploma. We therefore maintain that this work is very novel and original.

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CERTIFICATION OF CORRECTION OF THESIS

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LIST OF PUBLICATIONS AND OTHER CONTRIBUTIONS TO SCIENCE

Peer reviewed journal articles

1. Awazi, N.P., Tchamba, N.M., Avana, T.M.L. (2019). Climate change resiliency choices of small-scale farmers in Cameroon: determinants and policy implications. *Journal of Environmental Management 250 (2019) 109560*. https://doi.org/10.1016/j.jenvman.2019.109560
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Peer review record

- Performed over **400 reviews** for journals including Agroforestry Systems; Scientific African; SN Social Sciences; Current World Environment; African Journal of Agricultural Research; Asian Journal of Agricultural Extension, Economics & Sociology; International Journal of Plant & Soil Science; Journal of Experimental Agriculture International; International Journal of Biodiversity and Conservation; Journal of Agricultural Extension and Rural Development; Journal of Ecology and the Natural Environment; African Journal of Environmental Science and Technology; Journal of Development and Agricultural Economics; International Journal of Livestock Production; Asian Journal of Advances in Agricultural Research; Asian Journal of Research in Agriculture and Forestry; Journal of Horticulture and Forestry; International Journal of Environment and Climate Change; and Current Journal of Applied Science and Technology; placing in the 99th percentile for verified review contributions on Publons up until July 2020. Link: **https://publons.com/a/1538863**

DEDICATION

I dedicate this thesis to my lovely mother - Engoh Rose, and father - Nyong Jacob, and to all my brothers and sisters.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF APPENDICES

LIST OF ACRONYMS

AFPs: Agroforestry Practices

AFS: Agroforestry Systems

ANAFOR: Agence Nationale des Forêts

ANOVA: Analysis of Variance

BNL: Binomial Logistic Regression Model

CO_2: Carbon dioxide

CV: Coefficient of Variation

CVC: Climate Variability and Change

FCFA: *Franc des colonies françaises d'afrique*

FGDs: Focus Group Discussions

FAO: Food and Agricultural Organization of the United Nations

GDP: Gross Domestic Product

GHG: Green House Gases

IIA: Independence of Irrelevant Alternatives

IPCC: Inter-Governmental Panel on Climate Change

KIIs: Key Informant Interviews

MNL: Multinomial Logit Regression Model

NGO: Non-Governmental Organization

PP diagram: Probability Plot diagram

QQ diagram: Quantile Quantile diagram

REDD+: Reducing Emissions from Deforestation and Forest Degradation

SPSS: Statistical Package for Social Science

UNFCCC: United Nations Framework Convention on Climate Change

US$: United States Dollar

USAID: United States Agency for International Development

ABSTRACT

Climate variability and change is today one of the greatest existential threats facing humanity. The ravaging effects of this scourge spell doom for stakeholders involved in climate dependent sectors like agriculture. Promoting climate-smart practices that reduce vulnerability and enhance resilience becomes incumbent. It is within this framework that this study sought to assess the contributions of agroforestry practices towards the attenuation of vulnerability and the enhancement of resilience of smallholder farming systems in Cameroon in general and Mezam division, north western Cameroon in particular faced with climate variability and change. Both secondary and primary data were collected for the study. Secondary data collected included mainly climate data (temperature and rainfall). Primary data on its part was collected through household surveys, focus group discussions, key informant interviews, and inventories on smallholder farmers' agroforestry and non-agroforestry plots. Data collected was analyzed on SPSS 20, Excel 2007 and STATA 13 making use of descriptive and inferential statistics. From the results obtained, both smallholder farmers' perceptions and analyzed climate data revealed an increase in temperature and a marked reduction in the total quantity of rainfall in recent decades. It was also found that smallholder farmers perceived recurrent extreme weather events (99%) and poverty (96%) as the main drivers of vulnerability to climate variability and change. Household size, age of household head, household income, access to information, and access to land had a significant negative causal relationship ($p<0.05$) with smallholder farmers' vulnerability to climate variability and change demonstrating that these variables have a high propensity to reduce smallholder farmers' vulnerability. The main agroforestry practices of smallholder farmers were home gardens with livestock (53%), trees on croplands (48%), and home gardens (44%); with agroforestry practices categorized under the agrosilvicultural agroforestry system (with 7 practices) being the most dominant. The findings equally revealed that five agroforestry practices (home garden with livestock, trees on croplands, trees on grazing lands, coffee-based agroforestry and Taungya) had a strong negative causal relationship ($p<0.05$) with smallholder farmers' vulnerability to climate variability and change, which shows that these agroforestry practices play a major role towards reducing smallholder farmers' vulnerability. It was also found that four agroforestry practices (home garden with livestock, home gardens, trees on grazing lands and coffee-based agroforestry) had a significant positive causal relationship ($p<0.05$) with smallholder farmers' resilience to climate variability and change, which proves that these agroforestry practices play a major role towards enhancing smallholder farmers' resilience. Thus, agroforestry practices play a significant role towards reducing vulnerability and enhancing resilience of smallholder farmers faced with climate variability and change. Based on the findings of this study, it is highly recommended that agroforestry practices and systems be integrated into the mainstream as a best practice owing to its ability to reduce vulnerability and enhance resilience to climate variability and change especially for smallholder farmers.

Key words: Climate variability and change, vulnerability, resilience, agroforestry, smallholder farmers, farming system, Cameroon

RÉSUMÉ

Les changements climatiques est aujourd'hui considérés comme l'une des plus grandes menaces auxquelles l'humanité est confrontée. Les effets dévastateurs de ce fléau constituent un mauvais présage pour les acteurs impliqués dans les secteurs dépendant du climat tels que l'agriculture. Promouvoir des pratiques durables qui réduisent la vulnérabilité et améliorent la résilience devient essentielle. C'est dans ce cadre que s'est inscrite cet étude à travers l'examination des contributions des pratiques agroforestières à l'atténuation de la vulnérabilité et à l'amélioration de la résilience face aux changements climatiques, des systèmes de petites exploitations agricoles au Cameroun en général et du departement de la Mezam, nord-ouest du Cameroun en particulier. Si les données secondaires collectées comprenaient principalement des données climatiques (température et précipitations), les données primaires quant à elles ont été collectées grâce aux enquêtes auprès des ménages, les focus group, d'interviews des personnes ressources et d'inventaires sur des parcelles agroforestières et non-agroforestières des paysans. Ces données ont été analysées sur SPSS 20, Excel 2007 et STATA 13 en utilisant de statistiques descriptives et inférentielles. D'après les résultats obtenus, les perceptions des petits agriculteurs et les données climatiques analysées ont révélé une augmentation de la température et une réduction de la quantité totale de précipitations au cours des dernières décennies. Il a également été constaté que les paysans percevaient la récurrence des phénomènes météorologiques extrêmes (99%) et la pauvreté (96%) comme les principaux facteurs de vulnérabilité aux changements climatiques. De plus, la taille du ménage, le revenu du ménage, l'âge du chef de ménage, l'accès aux informations et l'accès à la terre avaient une forte relation de cause à effet négative ($p<0,05$) avec la vulnérabilité des paysans face aux changements climatiques, ce qui démontre que ces variables ont une forte propension à réduire la vulnérabilité des paysans. Les principales pratiques agroforestières des paysans étaient les jardins de case avec des animaux (53%), champs complantés d'arbres (48%) et des jardins de case (44%); les pratiques agroforestières classées sous les systèmes agrosylvicoles (avec 7 pratiques) étant les plus dominantes. Les résultats ont également révélé que cinq pratiques agroforestières (jardin de case avec des animaux, champs complantés d'arbres, arbres dispersés dans les pâturages, pratique agroforestière à base de café et Taungya) avaient une forte relation négative de cause à effet ($p<0,05$) avec la vulnérabilité des paysans face aux changements climatiques, ce qui signifie que ces pratiques agroforestières jouent un rôle important dans l'atténuation de la vulnérabilité des paysans. Il a également été constaté que quatre pratiques agroforestières (jardin de case avec des animaux, jardins de case, arbres dispersés dans les pâturages et pratique agroforestière à base de café) avaient une forte relation positive de cause à effet ($p<0,05$) avec la résilience des paysans face aux changements climatiques, ce qui démontre que ces pratiques agroforestières jouent un rôle important dans le renforcement de la résilience des paysans. Tout cela montre que les pratiques agroforestières jouent un rôle important dans l'atténuation de la vulnérabilité et le renforcement de la résilience des systèmes de petites exploitations agricoles confrontés aux changements climatiques. Sur la base des résultats de cette étude, il est vivement recommandé d'intégrer les pratiques et systèmes agroforestiers au centre des politiques en tant que pratiques durables en raison de leur capacité à atténuer la vulnérabilité et à améliorer la résilience des paysans face aux changements climatiques.

Mots clés: Changements climatiques, la vulnérabilité, la résilience, l'agroforesterie, paysans, système de l'exploitation agricole, Cameroun

CHAPTER ONE

INTRODUCTION

1.1. Background of the study

Combating climate change and its negative impacts features prominently amongst the seventeen United Nations Sustainable Development Goals (SDGs), agenda 2030 (United Nations Sustainable Development Summit, 2015; Burck *et al.,* 2016). This comes in the wake of dangerous changes in climate caused by increasing concentration of carbon dioxide (CO_2) and other green house gases (GHGs) in the atmosphere (especially over the last four decades), due principally to fossil fuel combustion and agricultural lands replacing tropical forests (IPCC, 2007; NAS and RS, 2014; IPCC, 2018; Paterson and Charles, 2019).

It is estimated that agricultural activities contribute to 13.5% of total anthropogenic GHG emissions and release mainly nitrous oxide (N_2O) and methane (CH_4) (roughly 45% of agricultural GHG emissions each), with CO_2 contributing the remaining share (Knopf *et al.*, 2010). With the increasing use of nitrogen fertilizers, increase in livestock numbers and more animal manure production, it is expected that N_2O and CH_4 emissions emanating from agriculture will increase by 35 to 60% by 2030 resulting to severe repercussions on the agricultural sector (Rayner *et al.,* 2015).

Climate variability and change threatens human existence in general and the livelihood of smallholder farmers in particular in the 21st century (Lambi, 2010; Tsalefac *et al.,* 2011; FAO, 2011; Meybeck *et al.,* 2018; Chanana-Nag and Aggarwal, 2018). Studies show that smallholder farmers will bear the greatest brunt of predicted changes in climate patterns owing to their limited adaptive capacity (FAO, 2016). These highly vulnerable smallholder farmers would easily succumb to climate-induced extreme weather events such as floods, prolonged dryness and/or droughts, excessive heat, erratic rainfall and storms leading to devastating impacts on crop and animal health as well as farmers' wellbeing, thus engendering food insecurity (FAO *et al.,* 2018; Tume and Tanyanyiwa, 2018). In the face of increasing climate variability and change, smallholder farmers are faced with two main options: adaptation and/or mitigation (UNFCCC COP21, 2015). However, implementing one or both options involves burdensome human, material and financial resources which smallholder farmers in the majority cannot afford as most lead subsistence lives (FAO, 2010).

In the developing world, it is estimated that there are roughly five hundred million smallholder farms, supporting almost two billion people, and in Asia and Sub-Saharan Africa, these small farms produce about 80% of the food consumed (IFAD, 2012). With an exponential increase in the number of smallholder farms in the developing world which in most cases are inherently unsustainable, there is absolute necessity to document and promote sustainable and agro-ecological options which can better combat the ravages of climate variability and change (Serdeczny *et al.,* 2016; Lewis *et al.,* 2018; Awazi and Tchamba, 2019).

Agroforestry is one of the best practices which can contribute to curb the ravages of climate variability and change in smallholder farming systems while at the same time enhancing resiliency and mitigation efforts (Lasco *et al.,* 2015; Awazi and Tchamba, 2019). With most climate change mitigation programmes in Africa in particular, focusing on reforestation and protection of tropical forests, a dilemma emerges between reducing tropical deforestation and expanding agricultural production to feed the ever growing African population (Mbow *et al.,* 2012; Mbow *et al.,* 2013). It is in this light that agroforestry comes in to solve the quandary between reforestation and agricultural production, for agroforestry increases carbon storage and may also enhance agricultural productivity (Kumar and Nair, 2012; Bishaw *et al.,* 2013; Awazi and Tchamba, 2019). Climate change mitigation initiatives in Africa, especially under the auspices of REDD+ should therefore take into cognizance the food needs of the population and not focus solely on reforestation and forest protection campaigns, for this sort of approach has often failed woefully (FAO, 2010). Smallholder farmers should therefore be encouraged to take up agroforestry for it contributes towards reducing vulnerability and enhancing resilience to climate variability and change (Lott *et al.,* 2009; Viswanath *et al.,* 2018).

African agriculture is dominated by smallholder farmers with food self-sufficiency being the main motivating factor (FAO, 2013; Tankou *et al.,* 2017; Niles and Salemo, 2018; Partey *et al.,* 2018). Climate change mitigation and adaptation measures therefore need to demonstrate that they can increase food production and provide multiple benefits capable of reducing vulnerability and enhancing resilience (Appiah *et al.,* 2018; Awazi and Tchamba, 2019). A multitude of studies have shown that agroforestry could provide multiple ecosystem services which therefore calls for more investment in the practice (Bishaw *et al.,* 2013; Nguyen *et al.,* 2013; Amare *et al.,* 2018). Presently, the contributions of agroforestry practices to the reduction of vulnerability and enhancement of smallholder farmers' resilience faced with

climate variability and change has not been substantially evaluated although there is growing evidence that the numerous ecosystem services provided by agroforestry systems could generate more financial capital which improves the capital accumulation of smallholder farmers (Noordwijk *et al.,* 2011; Thorlakson and Neufeldt, 2012). Some studies in particular have shown that agroforestry has the capacity to increase carbon storage and produce more livelihood assets for smallholder farmers (Bishaw *et al.,* 2013; Awazi and Tchamba, 2019).

In Cameroon like other parts of sub-Saharan Africa, food-focused production systems are a quintessential part of the agricultural sector (Kimengsi and Azibo, 2015; Azibo *et al.,* 2016; Kimengsi *et al.,* 2016; Awazi and Tchamba, 2018; Awazi *et al.,* 2019). These largely food-based production systems are primarily controlled by smallholder farmers who constitute above 80% of the farming population (Molua, 2006). Agroforestry practices constitute a major part of these food-based production systems in Cameroon (Asaah *et al.,* 2011; Njongue *et al.,* 2017; Munjeb *et al.,* 2018). However, despite the seemingly widespread nature of agroforestry practices in smallholder farming systems in Cameroon, little or no research has been undertaken to assess the contribution of agroforestry towards vulnerability reduction and resilience enhancement to climate variability and change. This study therefore sought to blaze a trail and illuminate new pathways by looking at how this somewhat ubiquitous and age-old practice (agroforestry) contributes to vulnerability attenuation and resilience enhancement in smallholder farming systems in Cameroon in general and the North-West Region of Cameroon in particular, faced with climate variability and change.

1.2. Statement of the problem

Agricultural production in the North-West Region of Cameroon in general and Mezam division in particular is presently threatened by climate variability and change coupled with other factors such as poverty, poor market access, limited inputs, severe soil degradation and limited access to credit facilities. Smallholder farmers' almost complete dependence on rain-fed agriculture for their livelihoods makes for a scenario where any variation in climate has direct repercussions on food production. Their vulnerability to extreme climate events is largely due to their limited adaptive capacity. Although smallholder farmers have little capacity to adapt to the adverse effects of extreme weather events, they have not just succumbed. They are increasingly resorting to and/or intensifying practices that can help them better adapt to and mitigate the adverse effects of the increasingly variable and changing climate.

One of the sustainable and agro-ecological farming systems practiced by smallholder farmers is agroforestry. However, despite the seemingly widespread nature of agroforestry practices, there exists a dearth of knowledge on how they contribute to attenuate vulnerability and enhance resilience in smallholder farming systems faced with climate variability and change. Given the predicted rate and magnitude of climate variability and change in the North-West Region of Cameroon in general and Mezam division in particular, it is imperative to document and promote the implementation of climate-smart practices like agroforestry in smallholder farming systems, in order to limit the ravaging impacts of climate variability and change on smallholder farmers. And because most small-scale farmers on their own may not be able to adjust their farming systems fast enough to match the rate of climate variability and change, low cost, environmentally benign and climate smart practices like agroforestry are of the essence. Agroforestry practices therefore hold the key to the future for smallholder farmers in the North-West Region of Cameroon in general and Mezam division in particular within the present dispensation of an increasingly variable and changing climate.

It was within this backdrop that this research work sought to examine the contribution of agroforestry to the attenuation of vulnerability and the enhancement of resilience to climate variability and change in smallholder farming systems in Mezam division, North-West Region of Cameroon. To accomplish this arduous task, the following main research question was posed:

- ❖ What is the contribution of agroforestry practices to the attenuation of vulnerability and the enhancement of resilience of smallholder farmers faced with climate variability and change in the North-West Region of Cameroon?

To provide plausible answers to the main research question, the following specific/secondary research questions were posed:

- ✓ What are the drivers of smallholder farmers' vulnerability to climate variability and change in Mezam division, North-West Region of Cameroon?
- ✓ What are the different agroforestry practices of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change?
- ✓ What is the role of agroforestry practices to the attenuation of vulnerability of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change?

- ✓ What are the contributions of agroforestry practices to the enhancement of resilience of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change?

To provide better answers to the main and specific research questions posed, main and specific objectives were set:

1.3. Objectives of the study

This study sought to attain the following main and specific objectives:

- ❖ **Main objective**
  - ✓ To contribute towards reducing vulnerability and enhancing resilience of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change through the documentation of agroforestry practices.
- ❖ **Specific objectives**
  - ✓ To assess the drivers of smallholder farmers' vulnerability to climate variability and change in Mezam division, North-West Region of Cameroon;
  - ✓ To characterize smallholder farmers' agroforestry practices in the face of climate variability and change in Mezam division, North-West Region of Cameroon;
  - ✓ To evaluate the role of agroforestry practices to the attenuation of vulnerability of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change;
  - ✓ To examine the contribution of agroforestry practices to the enhancement of resilience of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change.

1.4. Hypotheses of the study

For the aforementioned main and specific objectives to have more focus and objectivity, the following main and specific hypotheses were tested:

- ❖ **Main hypothesis**
  - ✓ Ecosystem services resulting from agroforestry practices contribute the most towards reducing vulnerability and enhancing resilience of smallholder

farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change.

- **Specific hypotheses**
  - ✓ Recurrent extreme weather events are the major driver of smallholder farmers' vulnerability to climate variability and change in Mezam division, North-West Region of Cameroon.
  - ✓ Agroforestry practices categorized under the agrosilvicultural agroforestry system are the most practiced by smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change.
  - ✓ Provisioning services of agroforestry contribute the most towards reducing the vulnerability of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change.
  - ✓ Provisioning services of agroforestry contribute the most towards enhancing the resilience of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change.

The main and specific hypotheses of the study were inspired by the research works of other authors who carried out research in the same line of study in Cameroon, Africa and the tropics in particular and the world in general:

The main hypothesis of the study which states that "ecosystem services resulting from agroforestry practices contribute the most towards reducing vulnerability and enhancing resilience of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change" was inspired by the research works of Verchot (2007); Mbow *et al.* (2013); Nguyen *et al.* (2013); and Awazi *et al.* (2019) which all demonstrated that ecosystem services resulting from smallholder farmers' agroforestry practices/systems could go a long way to enhance their adaptation to climate variability and change. It was therefore this line of thought that guided the stating of the main hypothesis of the study.

Meanwhile, the first specific hypothesis of the study which states that "recurrent extreme weather events are the main driver of smallholder farmers' vulnerability to climate variability and change in Mezam division, North-West Region of Cameroon" was inspired by the research works of Rurinda *et al.* (2014), Innocent *et al.* (2016), Fongnzossie *et al.* (2018) and Awazi *et al.* (2019). All these research works have in one way or the other proofed that reccurrent extreme weather events play some part in smallholder farmers' vulnerability to

climate variability and change. The findings of these studies therefore influenced the stating of this specific hypothesis.

The second specific hypothesis of the study which states that "agroforestry practices categorized under the agrosilvicultural system are the most practiced by smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change" was inspired by the scientific findings of Atangana *et al.* (2014), Lasco *et al.* (2015), Njongue *et al.* (2017), Viswanath *et al.* (2018), Awazi and Tchamba (2019) and Awazi *et al.* (2019). The findings of these research works demonstrated that most smallholder farmers take to agroforestry practices categorized or classified under the agrosilvicultural system (home gardens, trees on farmlands, improved fallows, live fences, Taungya, coffee-based agroforestry, and cocoa-based agroforestry) owing to the ease of management of these practices. These studies therefore guided the stating of this specific hypothesis.

The third specific hypothesis of the study which states that "provisioning services of agroforestry practices contribute the most towards reducing the vulnerability of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change" was inspired by the scientific works of Molua (2006), Bishaw *et al.* (2013), Nguyen *et al.* (2013), Vaast and Somarriba (2014), Kumar (2016); Mkonda and He (2017), Amare *et al.* (2018), and Awazi and Tchamba (2019). The findings of these research works showed that most smallholder farmers perceived provisioning services of agroforestry (food, fuelwood, traditional medicines, and building materials) as contributing towards aiding their adaptation efforts, thus reducing their vulnerability faced with climate variability and change. It was therefore within this context that this specific hypothesis was stated.

The fourth and last specific hypothesis of the study which states that "provisioning services of agroforestry play the most important role towards enhancing the resilience of smallholder farmers in Mezam division, North-West Region of Cameroon, faced with climate variability and change" was inspired by the scientific works of Bishaw *et al.* (2013), Mbow *et al.* (2013), Mbow *et al.* (2014), Awazi and Tchamba (2019), and Awazi *et al.* (2019). These studies found that, although agroforestry systems supply a plethora of ecosystem services, provisioning services play a critical role in improving smallholder farmers' adaptation to climate variability and change, which goes a long way to enhance their resilience.

As already mentioned, the main and specific hypotheses of the study were therefore inspired by the research works of various authors who carried out studies in different parts of

Cameroon, Africa and the tropics, producing technically sound and scientifically robust research findings. This implies that the main and specific hypotheses of this study are sound and robust enough to stand rigorous scientific tests, evidenced by the soundness of the scientific works from which inspiration was drawn.

It is worth mentioning that most of these studies either focused on climate change mitigation and adaption through agroforestry or laid emphasis on other aspects of agroforestry. This study is one of the first to examine the contributions of agroforestry towards the reduction of vulnerability and the enhancement of resilience to climate variability and change in smallholder farming systems in Cameroon in general and the North-West Region of Cameroon in particular.

1.5. Significance of the study

The significance of this study has been articulated around three sub-themes: scientific, practical and theoretical significance.

In the scientific domain, this study contributes immensely to the enrichment of science owing to its novelty and originality. With climate change wreaking havoc all across the globe, the necessity to promote practices that contribute towards attenuating vulnerability and enhancing resilience becomes incumbent. It is within this framework that this study focuses on the contributions of agroforestry (a best practice) towards attenuating vulnerability and enhancing resilience of smallholder farmers to climate variability and change. Thus, scientifically, the results of this study are very important.

Practically, this study is very important to small-scale farmers, Non-Governmental Organizations (NGOs) as well as local, national and international policy makers. To smallholder farmers, this study contributes towards assisting them in reducing their vulnerability and enhancing their resilience to climate variability and change as it documents different climate-smart agroforestry practices/systems. NGOs as well as local, national and international policy makers can use the results of this study to re-orientate their policy options pertaining to the attenuation of vulnerability and the enhancement of resilience to climate variability and change through the practice of agroforestry in smallholder farming systems.

Theoretically, this study adds more knowledge to the limited body of existing literature on the use of agroforestry to attenuate vulnerability and enhance resilience to climate variability and change in smallholder farming systems.

1.6. Thesis outline

This thesis contains five chapters. **Chapter one** is introductory and hence contains the background of the study, statement of the problem, research questions, objectives, hypotheses and significance of the study. **Chapter two** looks at literature review and embodies definition of key concepts, drivers of small-scale farmers' vulnerability to climate variability and change, contribution of agroforestry practices to the attenuation of vulnerability and the enhancement of resilience of smallholder farmers faced with climate variability and change, classification of agroforestry systems, trade-offs in agroforestry systems, tree diversity and density in agroforestry systems in sub-Saharan Africa, conceptual framework, and theoretical framework. **Chapter three** focuses on the methodology of the study and thus embodies description of the study site, sampling techniques, data collection procedures, data analysis procedure and limitations of the survey. **Chapter four** delves into results and discussion pertaining to drivers of smallholder farmers' vulnerability to climate variability and change, characterization of agroforestry practices, contribution of agroforestry practices to attenuation of vulnerability of smallholder farmers to climate variability and change, and the role of agroforestry practices to smallholder farmers' resilience enhancement in the face of climate variability and change. **Chapter five** looks at the conclusions, recommendations, and policy implications of the study.

CHAPTER TWO

LITERATURE REVIEW

2.1. Definition of concepts

2.1.1. Climate variability

The Inter-Governmental Panel on Climate Change (IPCC) defines climate variability as variations in the mean state of climate on all temporal and spatial scales beyond that of individual weather events. This may be internal variability (i.e. caused by natural processes within the climate system), or external variability (i.e. due to anthropogenic forcing) (IPCC, 2007).

2.1.2. Climate change

According to the IPCC, climate change refers to a change in 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, 2001; IPCC, 2007). Climate change may be caused by both natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (McCarthy *et al.* 2004; IPCC, 2007).

The United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change 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 is observed over comparable time periods" (UNFCCC, 2006). The UNFCCC therefore distinguishes between climate change attributable mainly to anthropogenic forcings which alter the atmospheric composition, and climate variability attributable to natural causes.

Today, climate change usually refers to changes in modern climate which is sometimes qualified as anthropogenic or human induced climate change or "Global Warming" (USAID, 2007; Biermann, 2007; FAO, 2018).

2.1.3. Resilience to climate variability and change

The IPCC defines resilience to climate variability and change as "the ability of a social or ecological system to absorb disturbances while retaining the same basic structure and ways of functioning, the capacity for self-organization, and the capacity to adapt to stress and change." Thus, the fundamental quality of resilience is the capacity to withstand shocks and rebuild when necessary (IPCC, 2001; IPCC, 2007). Following Turner et al, resilience refers to future actions that can improve a system's ability to cope with outside hazards (Turner et al., 2003). According to Folke *et al. (2010),* resilience can be socio-ecological which refers to the capacity for transformation when systems cross certain thresholds.

2.1.4. Vulnerability to climate variability and change

According to Adger et al, vulnerability to climate variability and change is "the degree to which a system is susceptible to or unable to cope with the adverse effects of climate change, including climate variability and extremes" (Adger *et al.,* 2007). Vulnerability to the impacts of climate variability and change is therefore a function of exposure to extreme climate conditions, sensitivity to those conditions, and the capacity to adapt to the changes (IPCC, 2007).

2.1.5. Adaptation to climate variability and change

Smit and Wandel define adaptation as a process, or an action undertaken by a system to improve its resilience to shock, stress or risk (Smit and Wandel, 2006).

Following the IPCC, adaptation to climate variability and change is defined as "the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2007).

Climate Change and Biodiversity (CBD) on its part defines adaptation as the responsive adjustment in natural or human managed systems to minimize the expected changes, its effects or impacts (CBD, 2008).

The IPCC categorizes adaptation to climate variability and change into two types: spontaneous and planned. Spontaneous adaptation occurs at the level of individuals whereas planned adaptation occurs at the level of the society or community (Berry *et al.*, 2006).

In the domain of agriculture, Smit and Skinner categorized adaptation into four main types: technological, on-farm adjustment practices, government policy including insurance, and diversification of household income sources (Smit and Skinner, 2002).

2.1.6. Mitigation of climate change

The IPCC defines mitigation as an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2001). Mitigation can equally take the form of limiting or controlling emissions of greenhouse gases so that the total accumulation is limited. It may also encompass attempts to remove greenhouse gases from the atmosphere (IPCC, 2001).

2.1.7. Smallholder or small-scale farmers

The term smallholder farmers which is interchangeably used with the terms "small-scale", "resource poor" and occasionally "peasant" farmers, refers to those farmers owning small-based plots of land on which they grow subsistence crops and one or two cash crops relying almost exclusively on family labour and for whom the farm provides the principal source of income (Morton, 2007; Ojwang *et al.*, 2010; IFAD, 2012). Generally, smallholder farmers are characterized by limited resource endowment relative to other farmers in the sector (ASAP, 2012).

2.1.8. Agroforestry

Agroforestry is a collective name for land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos) are deliberately used on the same land management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence (Nair, 1989; Nair, 1993). In agroforestry systems, there are both ecological and economic interactions between the different components.

Agroforestry can also be defined as a dynamic, ecologically based, natural resource management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits for land users at all levels (Leakey, 1996). Agroforestry systems are therefore multifunctional systems that can provide a wide range of economic, socio-cultural, and environmental benefits. According to Nair, there are three main types of agroforestry

systems: agrosilvicultural systems which are a combination of crops and trees; silvopastoral systems which combine forestry and grazing of domesticated animals on pastures, rangelands or on-farm; and agrosilvopastoral systems where trees, animals and crops are integrated on the same land management unit (Nair, 1993).

2.2. Effects of climate variability and change on smallholder farmers

Africa's smallholder farmers are increasingly being affected by climate change. Scholarship indicates that climate change has mainly adverse effects on Africa's smallholder farming communities. In a study carried out in Kenya, Herrero *et al.* (2010) found that climate change adversely affected smallholder farmers through recurrent droughts. Mary and Majule (2009) carried out a study in Tanzania, revealing that the recurrence of extreme climate events (changing rainfall and temperature patterns) led to increased risk of crop failure owing to the washing away of seeds and crops, stunted growth, poor seed germination, and withering of crops. It was equally found that, in the case of livestock, variations in rainfall patterns (decreased rainfall – drought) and increased rainfall – floods) led to a decrease in pasture and an increase in parasites and diseases. Similar findings have been reported by other studies carried out in Africa. Mortimore and Adams (2001) for example, found that the timing of the onset of the first rains and other intra-seasonal factors such as the effectiveness of the rains in each precipitation, and the distribution and length of the period of rain during the growing season seriously affects crop-planting regimes as well as the effectiveness and success of farming. According to the IPCC (2007), changes in rainfall patterns and the quantity of rainfall affects soil moisture and the rate soil erosion, both prerequisites for crop growth and crop yields. All these negatively affect smallholder farmers.

In a study assessing the economic impact of climate change on agriculture in Cameroon, Molua and Lambi (2006) found that as temperatures increases, and precipitation decreases, net revenue dropped across all the surveyed farms. The study equally revealed that an increase in temperature by 2.5°C will lead to a drop in net revenues from agriculture in Cameroon by $0.5 billion. A 5°C increase in temperature on its part will lead to a drop in net revenues by $1.7 billion. A 7% decrease in precipitation will lead to a drop in net revenues by $1.96 billion and a 14% decrease in precipitation will lead to a drop in net revenues from crops by $3.8 billion. The study however, found that increases in precipitation will lead to an increase in net revenues. Based on these findings, smallholder farmers in Cameroon will be adversely affected by climate change through a fall in farm revenue.

On their part, Tabi *et al.* (2012), in a study carried out in the Volta region of Ghana found that climate change adversely affects rice farmers. These adverse effects were death of animals, loss of farming capital, heat stress, increase in social vices, shortage of water, slow development, and increased poverty and food insecurity. From these findings and those of other studies aforementioned, it could be said that climate change has mainly adverse or negative effects on smallholder farmers in Africa.

2.3. Adaptation options implemented by small-scale farmers faced with climate change

In Africa, small-scale farmers have adopted different adaptive options in order to improve their adaptive capacity faced with climate change. Tabi *et al.* (2012) while assessing rice farming in the Volta region of Ghana found that rain-fed lowland rice farmers practiced different adaptive choices amongst which were the application of fertilizers, water management control practices, alternation of planting dates, herbicide use, and the use of high yielding and disease resistant varieties. On their part, Kuwornu *et al.* (2013) in a study carried out in northern Ghana found that smallholder farmers adopted both indigenous and introduced (modern) adaptive options to improve their adaptive capacity to climate change.

Molua and Lambi (2006), in a study undertaken in Cameroon, found that the main indigenous adaptation strategies implemented by smallholder farmers in the face of climate change were changing timing of farming operations, increasing planting space, undertaking traditional and religious ceremonies, change of crops, varying area cultivated, and cultivation of short season local varieties. The FAO (2006) found that the major indigenous adaptation strategies practiced by smallholder farmers were reducing food intake, change of crops, reducing personal expenditures, mortgaging land, homestead gardening, disposing of productive harvests, and re-sowing or re-planting.

Different authors have carried out studies across Africa with varying findings as far as indigenous adaptive choices implemented by smallholder farmers faced with climate change adversities are concerned. For example, studies carried out by Hassan and Nhemachena (2008); FAO (2009b); Gbetibouo (2009); Deressa *et al.* (2010) showed that diversification of crops is a major indigenous strategy practiced by smallholder farmers faced with climate change adversities. Studies carried out by Easterling *et al.* (2007); Boko *et al.* (2007); Gbetibouo (2009); FAO (2009b); FAO (2010); and Deressa *et al.* (2010) showed that the integration of livestock to crop production is a key indigenous strategy practiced by

smallholder farmers faced with climate change. Studies undertaken by Molua and Lambi (2006); Easterling *et al.* (2007); Boko *et al.* (2007); Hassan and Nhemachena., (2008); Gbetibouo, (2009) and FAO (2009b) revealed that changing the timing of farm operations is one of the most important indigenous strategies adopted by smallholder farmers in the face of climate change. The FAO (2006); Molua and Lambi (2006); FAO (2009b); and Gbetibouo (2009) found that changing of crops was a major adaptation strategy used by smallholder farmers to adapt to climate change. The FAO (2006) and Altieri and Koohafkan (2008) found that home gardening was a major indigenous strategy practiced by smallholder farmers faced with climate change adversities.

The FAO (2010a); Thorlakson (2011); Rao *et al.* (2011); Mbow *et al.* (2013a); Bishaw *et al.* (2013); Mbow *et al.* (2014); and Kabir *et al.* (2015) found that agroforestry practices like scattered trees on croplands, improved fallows, home gardens, cocoa, coffee and banana agroforests were sustainable and climate-smart adaptive choices practiced by smallholder farmers across Africa in the face of climate change.

From the foregoing, smallholder farmers are adopting both indigenous and introduced adaptive measures to adapt to the adverse effects of climate change across Africa. However, very little has been done so far to assess vulnerability and adaptive capacity (resilience) of smallholder farmers in the face of climate change, through the use of agroforestry.

2.4. Agroforestry for mitigation of and adaptation to climate change adversities in smallholder farming systems

Studies have shown that in the face of climate change adversities, agroforestry systems like scattered trees on croplands, improved fallows, home gardens, cocoa-based, coffee-based and banana-based agroforests constitute sustainable, environmentally benign and climate-smart adaptive options practiced mostly by smallholder farmers in the tropics (Latin America. Asia, and Africa) (FAO, 2010a; Thorlakson, 2011; Rao *et al.* 2011; Mbow *et al.* 2013; Bishaw *et al.* 2013; Mbow *et al.* 2014; Kabir *et al.* 2015; and Awazi and Tchamba, 2019). Based on the findings of the aforementioned studies, agroforestry systems can provide several ecosystem services to smallholder farmers' raising their adaptive capacity to climatic variations and changes. The four ecosystem services laid out by the MEA report (Millennium Ecosystem Assessment report) of 2005 i.e. regulating, provisioning, supporting and cultural services) (MEA, 2005), can all be obtained from agroforestry systems. The provisioning services obtained from agroforestry systems (fiber, medicines, food, building materials, wood) can

assist smallholder farmers to increase their sources of income – improving their adaptive capacity to climate change (Zomer *et al.,* 2009; Syampungani *et al.,* 2010; FAO, 2010a; Thorlakson, 2011; Noordwijk *et al.,* 2011; Nguyen *et al.,* 2012; Mbow *et al.,* 2013; Bishaw *et al.,* 2013; Kabir *et al.,* 2015).

Sub-Saharan Africa has experienced a major decline in soil fertility caused principally by extreme weather/climate events like droughts, floods, and desertification, all triggered by climate change (Mboh *et al.,* 2013). Sustainable agriculture is highly affected by declining soil fertility levels – as such agricultural practices depend largely on the natural fertility of the soil. Top soil erosion is the main cause of soil degradation and this is worsened by the washing away of crop residues and surface litter (Mbow *et al.,* 2013). In sub-Saharan Africa, poor agricultural policies, as well as high cost and scarcity of mineral fertilizers have made sustainable and climate-smart practices like agroforestry to come to the limelight (Mbow et al., 2014). Studies have shown that agroforestry has huge potentials to improve soil fertility (Charles *et al.* 2013; Mbow *et al.* 2013; Charles *et al.* 2014; Mbow *et al.* 2014). Based on the findings of these studies, the practice of agroforestry on farms enhances biological nitrogen fixation by leguminous trees/shrubs and increase soil organic matter. Also, they state that the presence of trees on farms improves the cycling of nutrients thereby enriching the soil with organic matter and nutrients while simultaneously contributing towards the improvement of soil structural properties. Thus, trees contribute towards improving organic matter in the soil, soil moisture conservation through the tapping of water from deeper layers of the soil and leaching prevention, as well as nutrients recovery. All these go to maintain soil fertility while enhancing smallholder farmers' adaptive capacity faced with climate change adversities.

In the present dispensation of recurrent extreme weather/climatic events caused by climate change, studies have shown that the yield gap can be reduced tremendously through the practice of agroforestry (Nguyen *et al.* 2012; Ekpo and Asuquo 2012; Kabir *et al.* 2015; and Awazi and Tchamba, 2019). These studies demonstrated the existence of a plethora of successful agroforestry technologies some of which included: rapidly growing trees/shrubs for fuelwood, medicinal trees/shrubs, local fruit trees/shrubs providing added income and nutrition, and trees/shrubs contributing towards soil fertility improvement. Following these studies, it is important to distinguish between simple or less complex agroforestry practices (like intercropping practices, hedgerow, and alley cropping) and complex agroforestry practices functioning more or less like natural forests ecosystems, found in agricultural

management systems. This is because in the face of climate change adversities, trade-offs need to be made between crop yields and the sustainability of the system. Faced with adverse climatic variations and changes, simple agroforestry practices are generally less sustainable than complex agroforestry (Awazi and Tchamba, 2019). Nevertheless, complex agroforestry systems produce far lesser crop yields than simple agroforestry practices. Thus, in the face of climatic variations and changes, simple agroforestry practices produce more crop yields but are less sustainable while complex agroforestry practices produce fewer crop yields but are more sustainable (Awazi and Tchamba, 2019). This therefore, calls for a trade-off in both systems.

From the foregoing, agroforestry practices/systems therefore, have the potential and capacity to increase the diversity of agro-ecosystems, provide several assets to farmers, and improve sustainable agricultural production which helps to enhance smallholder farmers' adaptation efforts in the face of climate change adversities (Charles *et al.,* 2014).

2.5. Causes of smallholder farmers' vulnerability to the impacts of climate variability and change

Smallholder farmers are amongst the most vulnerable to the adverse effects of climate variability and change, and several factors account for this vulnerability. Following the findings of Rurinda (2014), based on a study carried out in the smallholder farming systems of Zimbabwe, the causes of smallholder farmers' vulnerability to the impacts of climate variability and change were increased rainfall variability, lack of draught power, lack of fertilizer, lack of seed, declining soil fertility and lack of knowledge. According to Rurinda's findings, the main cause of smallholder farmers' vulnerability to the impacts of climate variability and change in the studied communities was increased rainfall variability.

On the other hand, a study undertaken by Tabi *et al.* (2012), on smallholder farmers' rice farms in the Volta region of Ghana showed that sources or causes of vulnerability of rice farmers to the negative impacts of climate variability and change were poor soils, few farmers engaged in off-farm activities, difficult land tenure system, low price of rice in the local market, lack of insurance in situations of crop failure, and limited or no access to credit facilities.

Equally, a study conducted by the Coping With Drought and Climate Change Project (Synthesis Report, 2009) in the Chiredzi district of Zimbabwe found out that, the principal

sources or causes of smallholder farmers' vulnerability to the impacts of climate variability and change were inherent dryness, high frequency of drought, mono-cropping (over-dependence on maize), poor farming practices, high incidence of poverty, limited alternative livelihood options outside agriculture, low access to technology (irrigation, seed), markets, institutions and infrastructure (poor roads, bridges, modern energy, dams and water conveyance), population pressure, skewed ownership and access to drylands livelihood assets such as livestock and wild-life, lack of drought preparedness plans, and limited use of climate early warning systems.

Studies conducted by Awazi (2016), and Awazi *et al.* (2019) in the North-West Region of Cameroon demonstrated that the principal sources of smallholder farmers' vulnerability to climate variability and change were poverty, inadequate rainfall, limited weather information as well as limited access to land. This goes to show that a combination of factors influenced smallholder farmers' vulnerability to climate variability and change.

From the findings of the aforementioned studies, it could be safely said that smallholder farmers in Cameroon, Africa and most of the developing world are highly vulnerable to the adverse effects of climate variability and change.

2.6. Agroforestry for vulnerability attenuation and resilience enhancement in smallholder farming systems faced with climate variability and change

Studies carried out by the FAO (2010a); Rao *et al.* (2011); Thorlakson (2011); Bishaw *et al.* (2013); Mbow *et al.* (2013a); Mbow *et al.* (2013b); Kabir *et al.* (2015); Awazi and Tchamba (2019) all demonstrated that agroforestry practices like home gardens, scattered trees on croplands, improved fallows, cocoa, coffee and banana agroforests constitute climate-smart and sustainable adaptation options implemented by smallholder farmers mostly in the developing economies of Africa, Asia, and Latin America in the face of climate variability and change. These studies found that agroforestry practices are low cost, climate-smart landuse systems which provide the four ecosystem services described by the Millennium Ecosystem Assessment report (provisioning, regulating, cultural, and supporting services) (MEA, 2005). Provisioning services in particular (food, fibre, medicines, wood, and building materials) provided by agroforestry practices help smallholder farmers to diversify their income sources thereby aiding their adaptation effort, thus making them more resilient in the face of climate variability and change (Zomer *et al.*, 2009; FAO, 2010a; Syampungani *et al.*,

2010; Noordwijk *et al.,* 2011; Thorlakson, 2011; Nguyen *et al.,* 2012; Bishaw *et al.,* 2013; Mbow *et al.*, 2013a; Kabir *et al.,* 2015; Quandt *et al.*, 2017; Quandt *et al.,* 2018).

Today, soil fertility decline is a major concern in sub-Saharan Africa due mainly to different drivers amongst which is increasing variability and change in climate patterns. This steady decline is soil fertility seriously affects sustainable agriculture (Mboh *et al.,* 2013a). Soil degradation is the direct result of top soil erosion which is exacerbated by the washing away of surface litter and crop residues. With the scarcity and high cost of mineral fertilizers coupled with the lackluster performance of agricultural policies in most sub-Saharan African countries, discussions on sustainable best practices like agroforestry have gained grounds (Mbow et al., 2013b). Agroforestry's potential to enhance soil fertility has been documented by several studies. These studies spearheaded by Mbow *et al*. (2013a), Mbow *et al.* (2013b), Charles *et al.* (2013), Charles *et al.* (2014) all argue that the practice of agroforestry on farms increases soil organic matter and biological nitrogen fixation especially by leguminous trees. They further state that trees on farms enhance nutrient cycling and enrich the soil with nutrients and organic matter while at the same time improving the structural properties of the soil. Hence, trees help to improve soil organic matter, recover nutrients and conserve soil moisture through water tapping from deeper soil horizons and prevention of leaching, thereby maintaining the fertility of the soil which goes a long way to reduce vulnerability and enhance resilience to climate variability and change.

Studies have also shown that agroforestry has huge potentials to reduce the yield gap in the context of increasing variability and changes in climate. These studies led by Ekpo and Asuquo (2012), Nguyen *et al.* (2012), Kabir *et al.* (2015) and Awazi and Tchamba (2019) demonstrate that there are a good number of successful agroforestry technologies like trees providing medicinal plant products, fast growing trees for fuelwood, indigenous fruit trees that provide added nutrition and income, as well as trees that improve soil fertility. These authors however spell out the necessity to differentiate between complex agroforestry practices integrated in agricultural management systems which function more or less like natural forests ecosystems and simple agroforestry practices (such as hedgerow, alley cropping and intercropping practices). This is because compromises and/or trade-offs need to be made between sustainability of the system and crop yields, faced with climate variability and change. Complex agroforestry practices are generally more sustainable than simple agroforestry practices, in the face of climate variability and change (Awazi and Tchamba,

2019). However, simple agroforestry practices produce more crop yields than complex agroforestry practices in the face of climate variability and change (Awazi and Tchamba, 2019). Some compromise and/or trade-off is therefore needed in both systems.

Thus, agroforestry practices have the capacity to provide farmers with numerous assets, enhance sustainable agricultural production and increase agro-ecosystem diversity which helps reduce vulnerability and build resilience, faced with the adverse effects of climate variability and change (Charles *et al.,* 2014).

2.7. Classification of and major tradeoffs in agroforestry systems

2.7.1. Classification of agroforestry systems in sub-Saharan Africa

Agroforestry systems can be categorized based on several criteria which include structural basis (spatial arrangement of the woody component, vertical stratification of all the components, and temporal arrangement of the different components); functional basis (the major function of the system, especially the role of the woody component); socioeconomic basis (intensity of management and commercial goals); Ecological (environmental condition and ecological suitability of systems) (Nair, 1993; Atangana *et al.,* 2013). Based on all these criteria, three main agroforestry systems emerge: agrosilvicultural, silvopastoral and agrosilvopastoral agroforestry systems. These three major agroforestry systems are made up of several different practices (Rao *et al.,* 2007). The agrosilvicultural system for example is made up of practices like improved fallows, Taungya, alley cropping, tree gardens, multipurpose trees on croplands, home gardens, live fences (Viswanath *et al.,* 2018). The silvopastoral system on its part is made up of practices like trees on rangelands, fodder banks, estate crops with pasture. Meanwhile the agrosilvopastoral system consists of practices like home gardens with livestock, multipurpose woody hedgerows, aquaforestry. All these agroforestry systems and practices are ubiquitous in sub-Saharan Africa (Amonum *et al.,* 2009; Mbow *et al.,* 2013a; Awazi and Tchamba, 2019).

2.7.2. Major trade-offs in agroforestry systems in sub-Saharan Africa

In sub-Saharan Africa, food-based production systems are a major part of the agricultural setup. With the population growing very rapidly, there is increasing urgency to increase food production in order to meet the growing food needs. It is for this reason that most smallholder farmers – who constitute a bulk of the farming population, have resorted to unsustainable but

high food yielding agricultural systems. This therefore means that sustainability is compromised in favour of crop yields. It is within this backdrop that agroforestry systems come in. Agroforestry systems are sustainable, agro-ecological and climate-smart, providing the four ecosystem services defined by the Millennium Ecosystem Assessment report (MEA, 2005). These include provisioning services (fibre, food, fodder, fuelwood, timber, water, finance); regulating services (climate regulation, disease, flood, waste, and water quality control); cultural services (recreation, aesthetics, spiritual); and supporting services (soil formation, photosynthesis, nutrient cycling) (Kumar, 2016; Mkonda and He, 2017). Agroforestry therefore has the potential to ensure the sustainability of farming systems while at the same time enhancing food production (Atangana et al., 2013). There is however some tradeoff to be made between the conflicting goals of food production and attaining sustainability (Mbow *et al.*, 2013a; Vaast and Somarriba, 2014). This is because while agroforestry systems can play a very big role in ensuring sustainability of agricultural systems, their role in the enhancement of food production is not too significant (Awazi and Tchamba, 2019). Nevertheless, agroforestry's collective role in balancing out both food production and sustainability is far greater than many other farming systems (Andreotti *et al.*, 2017) – thus the necessity for smallholder farmers to practice agroforestry, especially in the prevailing dispensation of climate variability and change.

2.8. Tree diversity and density in agroforestry systems in sub-Saharan Africa

In sub-Saharan Africa, studies have shown that tree densities in agroforestry systems range from as low as 5% tree cover in the Sahel to above 45% tree cover in the humid tropical zones where oil palm, cocoa and coffee agroforestry systems dominate (Mbow *et al.*, 2013b). In the same light, this study found that in sub-Saharan Africa, 15% of farms have at least a tree cover of 30%. Endale *et al.* (2017) in a study conducted in the semi-arid East Shewa region of Ethiopia found that agroforestry systems are characterized by varied levels of tree diversity. According to the findings of this study, 77 tree species belonging to 32 families were identified. The study however found that tree diversity varied across different land uses (woodlots, home gardens, croplands and line plantings), with the highest diversity occurring in line plantings and the lowest in woodlots. Ajake (2012) in a study conducted in the Cross River State of Nigeria found that a diversity of forest and non-forest tree species was found in the farming systems of the indigenous population. In total, 19 indigenous tree species were commonly found in the farming systems of the local population. Zomer *et al.* (2014) found

that tree cover in agricultural lands in sub-Saharan Africa, increased by 2% between the years 2000 to 2010. This increase is however slow when compared to South America (12.6% increase), South Asia (6.7% increase), East Asia (5% increase), Oceania (3.2% increase), and Southeast Asia (2.7% increase) (Zomer *et al.*, 2014). Meanwhile Bishaw *et al.* (2013) in studies conducted in Ethiopia and Kenya found high levels of tree diversity and density in different agroforestry systems like home gardens, rotational woodlots, alley cropping, live fences, and fodder banks. However, the highland home garden agroforestry system of the Gedeo region of Ethiopia was found to have a higher tree diversity and density than the arid pastoral agroforestry system in the Afar region located in North-Eastern Ethiopia. In Kenya, agroforestry systems in the Meru highlands were found to have more tree diversity and density than their counterparts in the Kibwezi district which is more arid. In the same light, Negawo and Beyene (2017) equally conducted a study in the Eastern part of Uganda which demonstrated that coffee-based agroforestry systems were characterized by high levels of tree diversity which contributed enormously to tree resources conservation in Eastern Uganda.

2.9. Theoretical and conceptual frameworks

2.9.1. Theoretical framework

This study is modeled around the determinants of smallholder farmers' practice of agroforestry and choice of agroforestry system faced with climate variability and change. With climate variability and change wreaking havoc on smallholder farming systems, smallholder farmers are increasingly making use of agroforestry to reduce vulnerability and enhance resilience to climate variability and change. Assessing the determinants of smallholder farmers' practice of agroforestry and choice of agroforestry system in the face of climate variability and change is therefore imperative. To do this, the study adapts the random utility model developed by Greene (2003). Thus, suppose that Y_j and Y_k represent a smallholder farmer's utility for two agroforestry systems, which are denoted by U_j and U_k , respectively. The linear random utility model could then be expressed as follows:

$$U_j = \beta'_j X_i + \varepsilon_j \text{ and } U_k = \beta'_k X_i + \varepsilon_k \qquad \text{Equation 2.1}$$

Where U_j and U_k are hypothesized utilities of agroforestry system j and k respectively, X_i is the vector of independent variables that influence the perceived desirability of the system, β_j and β_k are parameters to be estimated, and ε_j and ε_k are error terms assumed to be independently and identically distributed (Greene 2003).

In order to reduce vulnerability and enhance resilience to climate variability and change, if a smallholder farmer decides to use agroforestry system *j*, it follows that the perceived benefit from agroforestry system *j* is greater than the benefit from other agroforestry systems (say *k*). This can be demonstrated as follows:

$$U_{ij}\ (\beta'_j X_i\ +\ \varepsilon_j) > U_{ik}(\beta'_k X_i\ +\ \varepsilon_k),\ \mathrm{k} \neq \mathrm{j} \qquad \text{Equation 2.2}$$

The probability that a smallholder farmer, in the face of climate variability and change will use agroforestry system *j* among the set of different agroforestry systems could be expressed as:

$$P(Y = 1/X) = P\left(U_{ij} > U_{ik}\right)$$

$$P\left([\beta'_j X_i + \varepsilon_j] - [\beta'_k X_i - \varepsilon_k] > 0/X\right)$$

$$P\left([\beta'_j X_i - \beta'_k X_i] + [\varepsilon_j - \varepsilon_k] > 0/X\right)$$

$$P(X^* X_i + \varepsilon^* > 0/X = F(\beta^* X_i) \qquad \text{Equation 2.3}$$

Where *P* is a probability function, U_{ij}, U_{ik},, and X_i are as defined above, $\varepsilon^* = \varepsilon_j - \varepsilon_k$ is a random disturbance term, $\beta_j^* = (\beta'_j - \beta'_k)$ is a vector of unknown parameters that can be interpreted as a net influence of the vector of independent variables influencing the implementation of a given agroforestry system, and $F(\beta^* X_i)$ is a cumulative distribution function of ε^* evaluated at $\beta^* X_i$. The exact distribution of *F* depends on the distribution of the random disturbance term, ε^*. Following Greene (2003), a multitude of qualitative choice models can be estimated depending on the assumed distribution that the random disturbance term follows.

For this study, the multinomial logit (MNL) regression model was used. This model has been used by several studies (Kurukulasuriya and Mendelsohn, 2007; Deressa *et al.,* 2008; Tabi *et al.,* 2012; Kuwornu *et al.,* 2013; Atinkut and Mebrat, 2016) to explain the determinants of farmers' choices of adaptation options when faced with climate variability and change. However, this study investigated the determinants of the choice of agroforestry systems used by smallholder farmers to reduce vulnerability and enhance resilience to climate variability and change. According to Wooldridge (2002) and Koch (2007) the strengths of the multinomial logit (MNL) regression model include: permitting the analysis of decisions

across more than two categories; allowing the determination of choice probabilities for different categories, as well as the ease of interpreting estimates of the model.

In order to describe the multinomial logit (MNL) regression model, we consider that *y* represents a random variable (in this case different agroforestry systems of smallholder farmers) with the values (1, 2...*J*) for *J*, a positive integer, and consider that *x* represents a set of explanatory variables. Hence y represents categories (different agroforestry systems) and *x* denotes smallholder farmers' attributes: access to information, access to land, household income, access to extension services, access to credit. The question is how cetiris paribus changes in the elements of *x* affect the response probabilities *P* (*y* = *j* / *x*), *j* =1, 2,....*J*. Since the probabilities must sum to unity, *P*(*y* = *j* / *x*) is determined once we know the probabilities for *j* = 2,...*J* .

Suppose *x* to be a 1× *K* vector with first element unity. The MNL model has response probabilities as follows:

$$P(y = j / x) = \frac{\exp(x\beta_j)}{1 + \sum_{k=1}^{j} \exp(x\beta_k)}, j = 1, \ldots\ldots\ldots J \qquad \text{Equation 2.4}$$

Where β_j is K × 1, j = 1 ……..J

However, unbiased and consistent parameter estimates of the multinomial logit (MNL) regression model require the assumption of Independence of Irrelevant Alternatives (IIA) to hold. This implies that the probability of choosing a certain agroforestry system by a given smallholder farmer needs to be independent from the probability of choosing another agroforestry system (that is, P_j/P_k is independent of the remaining probabilities). The premise of the IIA assumption is the independent and homoskedastic disturbance terms of the basic model in equation 2.1.

The parameter estimates of the MNL regression model provide only the direction of the effect of the independent variables on the dependent (response) variable, but estimates do not represent either the actual magnitude of change nor probabilities. Differentiating equation 2.1 with respect to the explanatory variables provides marginal effects of the explanatory variables given as:

$$\frac{\partial P_j}{\partial X_k} = P_j\left(\beta_{jk} - \sum_{J=1}^{J-1} P_j \beta_{jk}\right) \qquad \text{Equation 2.5}$$

The marginal effects are usually derived to explain the effects of the independent variables on the dependent variable in terms of probabilities as seen in equation 2.5. The marginal effects measure the expected change in the likelihood of choice of a particular dependent variable with respect to a unit change in the independent or exogenous variable (Greene, 2003).

Variables considered for the multinomial logistic (MNL) regression model

The model integrated both explanatory variables and the dependent variable:

A. Explanatory variables

The exogenous, independent or explanatory variables that influence smallholder farmers' choice of agroforestry system in the face of climate variability and change in Mezam division, North-West Region of Cameroon were broadly classified under three main headings namely: socio-economic, institutional and environmental factors.

(a) Socio-economic factors

Several studies have been undertaken in different parts of Africa and the tropics demonstrating that socio-economic factors such as age, level of education, sex, land tenure, level of income, training, information received and so forth tremendously influence smallholder farmers' choice of adaptation options when face with the effects of climate variability and change (Deressa *et al.*, 2008; Tabi *et al.,* 2012; Kabir *et al.,* 2015; Atinkut and Mebrat, 2016; Taruvinga *et al.*, 2016; Awazi, 2016; Awazi *et al.*, 2019). For this study, the hypothesized socio-economic factors determining the choice of agroforestry system of smallholder farmers to reduce vulnerability and enhance resilience faced with climate variability and change were: household size, sex of household head, age of household head, number of farms, farm size, farm experience, educational level of household head, access to land, and household income.

(b) Institutional factors

Equally, studies on adaptation to climate variability and change undertaken in different parts of Africa and the tropics have shown that institutional factors largely influence smallholder farmers' choice of adaptation options. Some of these institutional factors such as access to credit, integrated warning systems, frequency of agricultural extension visits and existence of markets largely determine smallholder farmers' choice of adaptation options (Nhemachena and Hassan, 2007; Hassan and Nhemachena, 2008; Gbetibouo, 2009; Deressa *et al.*, 2010;

Mandleni and Anim, 2011; Atinkut and Mebrat, 2016; Taruvinga *et al.*, 2016; Awazi, 2016; Awazi *et al.,* 2019). For this study the hypothesized institutional variables influencing smallholder farmers' choice of agroforestry system to reduce vulnerability and enhance resilience to climate variability and change were: access to credit, access to information, access to extension services, and access to markets.

(c) Environmental factors

A multitude of studies have been undertaken in Africa and the tropics showing that environmental factors especially temperature, rainfall, sunshine and storms go a long way to influence smallholder farmers' choice of adaptation options when faced with the adverse impacts of climate variability and change (Nhemachena and Hassan, 2007; Hassan and Nhemachena, 2008; Gbetibouo, 2009; Deressa *et al.,* 2010; Mandleni and Anim, 2011; Atinkut and Mebrat, 2016; Awazi, 2016; Mensah-Bonsu *et al.,* 2017; Awazi *et al.,* 2019). In this study, the hypothesized environmental factor influencing smallholder farmers' choice of agroforestry system to reduce vulnerability and enhance resilience to climate variability and change was: variation in climate parameters (rainfall and temperature).

B. Dependent variable

The dependent variable for this study was the different agroforestry practices implemented by smallholder farmers in their farming systems, faced with climate variability and change. However, most scholarship found that smallholder farmers' adaptation measures are always numerous, hence the need to categorize them into fewer and more comprehensive groups in order to ease analysis (Gbetibouo, 2009; Deressa *et al.,* 2010; Kuwornu *et al.,* 2014; Atinkut and Mebrat, 2016; Awazi, 2016; Awazi *et al*., 2019). This research work therefore followed a similar framework by categorizing the numerous agroforestry practices taken up by smallholder farmers into three major categories: agrosilvicultural; silvopastoral; agrosilvopastoral agroforestry systems with the reference category being "No Agroforestry". Agroforestry practices categorized under agrosilvicultural agroforestry system were home gardens, coffee-based agroforestry, trees on croplands, live fences/hedges, Taungya, and improved fallows. Agroforestry practices categorized under silvopastoral agroforestry system were trees on grazing lands and fodder banks. Agroforestry practices categorized under the agrosilvopastoral agroforestry system were home gardens with livestock, and trees on rangelands with crops. The "No Agroforestry" category stood alone and constituted the reference category for the multinomial logit regression model.

2.9.2. Conceptual framework

The conceptual framework of the study is articulated around two major sub-concepts: vulnerability and resilience.

2.9.2.1. Vulnerability framework

The study makes use of the indicator method to examine the vulnerability of smallholder farming systems (agroforestry and non-agroforestry systems) faced with climate variability and change. This method quantifies the vulnerability of smallholder farming systems (agroforestry and non-agroforestry systems) based on some indicators. Several indicators can be used to examine the vulnerability of smallholder farming systems to climate variability and change. Following the IPCC (2001), vulnerability to climate variability and change is a function of three basic indicators namely: exposure, sensitivity and adaptive capacity (resilience) (Figure 2.1). Exposure is interpreted as the direct danger (i.e., the stressor), and the nature and extent of changes to a region's climate variables (e.g., temperature, precipitation, extreme weather events) while sensitivity describes the human-environmental conditions that can worsen the hazard, ameliorate the hazard, or trigger an impact. Adaptive capacity on its part represents the potential to implement adaptation measures that help avert potential impacts.

In this study, exposure hinges on two main elements; frequency of climate extremes and predicted changes in temperature and rainfall:

One of the main constraints to agriculture in the North-West Region of Cameroon is extreme climate events, which historically included frequent storms and prolonged dry spells. Hence with such recurrent extreme climate events, crop production is more risky. Predicted change in temperature and rainfall for Mezam division, North-West Region of Cameroon shows that there will be increased temperature and decreased rainfall in the coming decades (Tingem *et al.,* 2008). These changes will expose smallholder farming systems (agroforestry and non-agroforestry systems) to greater extreme climate events to which they would have more difficulties adjusting thereby negatively impacting farm production.

Pertaining to sensitivity, the study examines four factors that influence sensitivity to climate variability and change for a predominantly agricultural zone like Mezam division, North-

West Region of Cameroon; percentage of smallholder farmers, rural population density, rate of irrigation, and number of farmers taking to climate-smart practices like agroforestry:

Firstly, it is hypothesized that the percentage of smallholder farmers in an area greatly influences sensitivity (Turner *et al.*, 2003). This is because smallholder farmers in most cases are subsistence farmers with less capital-intensive technologies and management practices. Thus, a zone like Mezam division, North-West Region of Cameroon with a large number of smallholder farmers is highly sensitive to climate variability and change.

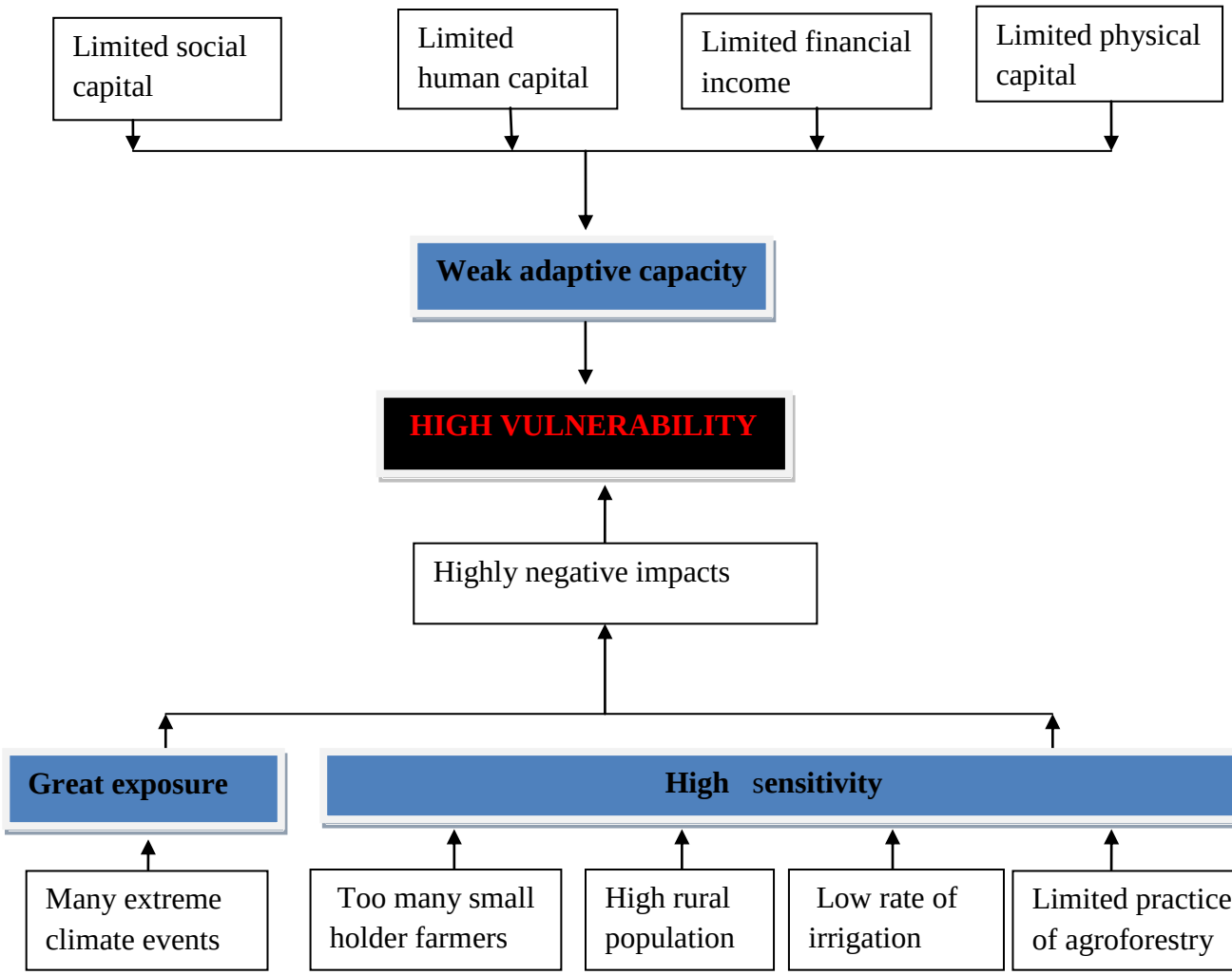

Figure 2.1: Vulnerability framework for smallholder farming systems (agroforestry and non-agroforestry systems) in the the North-West Region of Cameroon

Source: Adapted from Gbetibouo and Ringler (2009)

Secondly, it is hypothesized that rural population density has a direct influence on sensitivity to climate variability and change (Gbetibouo and Ringler, 2009). This is because rural

population's are the most vulnerable to climate variability and change owing to high rates of poverty, illiteracy and the unavailability of basic infrastructures to aid adaptation efforts in the face of climate variability and change. Mezam division, North-West Region of Cameroon characterized by very high rural population densities is therefore more sensitive to climate variability and change.

Thirdly, it has been hypothesized that the rate of irrigation equally influences sensitivity to climate variability and change (IPCC, 2007). This is because proper irrigation systems can help a great deal in times of extreme weather events like prolong dry spells or droughts. In Mezam division, North-West Region of Cameroon, less than 1% of the smallholder farming population undertakes irrigation, as an overwhelming majority practice a rain-fed system of agriculture. This therefore renders smallholder farming systems (agroforestry and non-agroforestry systems) in Mezam division, North-West Region of Cameroon more sensitive to climate variability and change.

Last but not the least the practice of sustainable and climate-smart farming systems like agroforestry also influences sensitivity (FAO, 2016). This is because agroforestry practices permit diversification in the farming system thereby limiting sensitivity to climate variability and change. In Mezam division, North-West Region of Cameroon, the increasing drive towards monoculture systems in order to have better crop yields makes smallholder farming systems (agroforestry and non-agroforestry systems) in the region highly sensitive to the vagaries of climate variability and change.

With respect to adaptive capacity, emphasis was laid on four livelihood assets; social capital, human capital, financial capital, and physical capital:

To start with, social capital consists of farm organizations (the number of farmers in organized agriculture). It is hypothesized that social capital positively influences adaptive capacity (resilience) to climate variability and change (IPCC, 2001; Awazi, 2016; Fongnzossie *et al.,* 2018; Quandt, 2018; Quandt, 2019; Awazi *et al.,* 2019). This is because smallholder farmers who belong to farm organizations are more aware of environmental changes and new agricultural technologies owing to information sharing during meetings which helps to beef-up resilience. However in Mezam division, North-West Region of Cameroon, there are relatively few smallholder farmers' organizations which go to limit the adaptive capacity of smallholder farming systems (agroforestry and non-agroforestry systems) in the face of climate variability and change.

Secondly, human capital embodies literacy rate and rate of prevalence of HIV/AIDS and other diseases. On the whole, increased literacy enhance adaptive capacity because it increases farmers' capabilities and access to information, thereby improving their ability to cope with adversities, meanwhile higher rates of prevalence of HIV/AIDS and other diseases reduce adaptive capacity because it renders smallholder farmers unhealthy and unable to farm (Gbetibouo and Ringler, 2009; Awazi, 2016). High rates of illiteracy coupled with relatively high rates of prevalence of HIV/AIDS and other diseases amongst smallholder farmers reduce adaptive capacity of smallholder farming systems (agroforestry and non-agroforestry systems) in Mezam division, North-West Region of Cameroon faced with climate variability and change.

In addition, financial capital which consists of farm income, farm holding size, farm assets and access to credit seriously influences adaptive capacity. It is hypothesized that higher farm income, larger farms, greater farm value assets, and more access to credit contribute to a better adaptive capacity in the face of climate variability and change (Turner *et al.,* 2003; IPCC, 2007; Quandt, 2018). This is because these assets permit the farmers to acquire better agricultural technologies and inputs which go a long way to aid the farmers' adaptation drive in the face of climate variability and change. In Mezam division, North-West Region of Cameroon, farm income is low, farm sizes are small, farm value assets are few, and there is limited access to credit facilities which limit adaptive capacity of smallholder farming systems (agroforestry and non-agroforestry systems) in the face of climate variability and change.

Last but not the least; physical capital embodies infrastructure and access to markets. It is hypothesized that good infrastructural facilities help to beef-up famers' adaptive capacity to climate variability and change (Deressa *et al.,* 2009; Fongnzossie *et al.,* 2018; Awazi and Tchamba, 2018; Quandt, 2018; Awazi *et al.,* 2019). This is because, improved infrastructure reduce transactions costs, and strengthen the links between labour and product markets. Markets on their part are a means of linking people both spatially and over time. Better and easily accessible markets therefore enhance smallholder farmers' adaptive capacity in the face of climate variability and change (Gbetibouo and Ringler, 2009). However, Mezam division, North-West Region of Cameroon is characterized by few infrastructural facilities and limited properly functional markets (especially in smallholder farming communities)

which go to limit the adaptive capacity of smallholder farming systems (agroforestry and non-agroforestry systems).

2.9.2.2. Resilience framework

The concept of resilience is very important in the context of studies pertaining to climate variability and change. It is a concept which examines the coping capacity of individuals, households, communities and even countries in the face of climate variability and change. Resilience focuses on a desired pathway of development, often assessed in terms of GDP per capita, yield, household income, or agricultural production (Gordon, 2009). In the context of this study, this pathway of development represents smallholder farming systems in Mezam division, North-West Region of Cameroon. These smallholder farming systems are often subject to climate-related stresses or shocks. A stress is a more predictable and less abrupt event such as rising maximum or minimum temperatures or the effects of a continuously drier climate. A shock on the other hand is an abrupt and less predictable event such as a drought or storm (Figure 2.2).

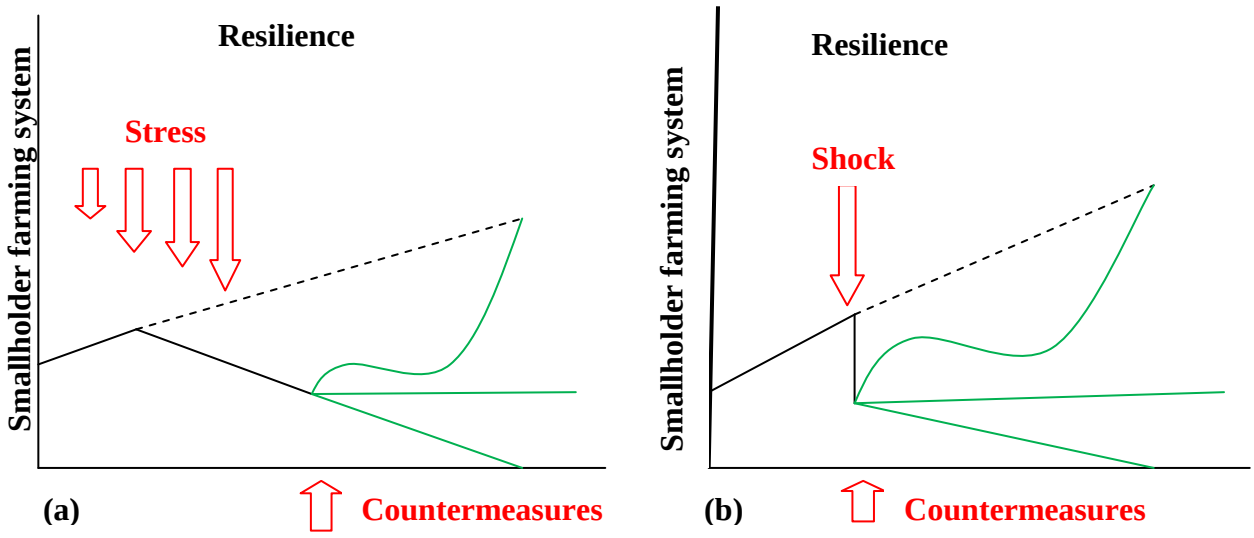

Figure 2.2: Patterns of resilience to climate variability and change in smallholder farming systems (agroforestry and non-agroforestry systems) in Mezam division, North-West Region of Cameroon: (a) to stress (b) to shock.

Source: Adapted from Gordon (2009)

Figure 2.2 (a) and (b) show the trends that occur is a smallholder farming system when faced with a climate-related stress or shock. Climate related stresses or shocks are regular occurrences in smallholder farming systems in the North-West Region of Cameroon. In some

circumstances, smallholder farming systems withstand these stresses or shocks. However, in other situations, smallholder farming systems are adversely affected, recovering either rapidly or slowly. At other times, the stresses or shocks become too much that recovery becomes impossible and the system collapses. This occurs for example when a major fire ravages a smallholder farm or a storm pulls down a large number of cash crops (banana, rubber, oil palms) in a smallholder farm. It must however be said that there are usually appropriate countermeasures for each stress or shock.

One of such countermeasures which constitute the main thrust of this study is agroforestry. Agroforestry is an agro-ecological, environmentally benign and climate-smart practice. In this study, it was hypothesized that smallholder farmers practicing agroforestry are more resilient to climate variability and change, than their counterparts involved in non-agroforestry practices. This has been attributed to the many ecosystems services provided by agroforestry systems when compared to non-agroforestry systems. Studies such as those conducted by Syampungani *et al.* (2010), Bishaw *et al.* (2013), Mbow *et al.* (2014), and Awazi and Tchamba (2019) have demonstrated that agroforestry systems through the ecosystem services they provide, can play a major role in aiding climate change adaptation and mitigation efforts especially among smallholder farmers. It must however be said that these studies did not assess the contribution of agroforestry practices towards the enhancement of smallholder farmers' resilience faced with climate variability and change, which was the knowledge gap this study sought to fill.

CHAPTER THREE

MATERIALS AND METHODS

3.1. Description of the study site

The study was carried out in the North-West Region of Cameroon – specifically in Mezam division (**Figure 3.1**). Mezam Division is one of the seven divisions found in the North-West Region of Cameroon. It is located between longitude 10°08' to 10°12' E and latitude 5°55' to 6°00' N. It covers a surface area of 1745 km^2.

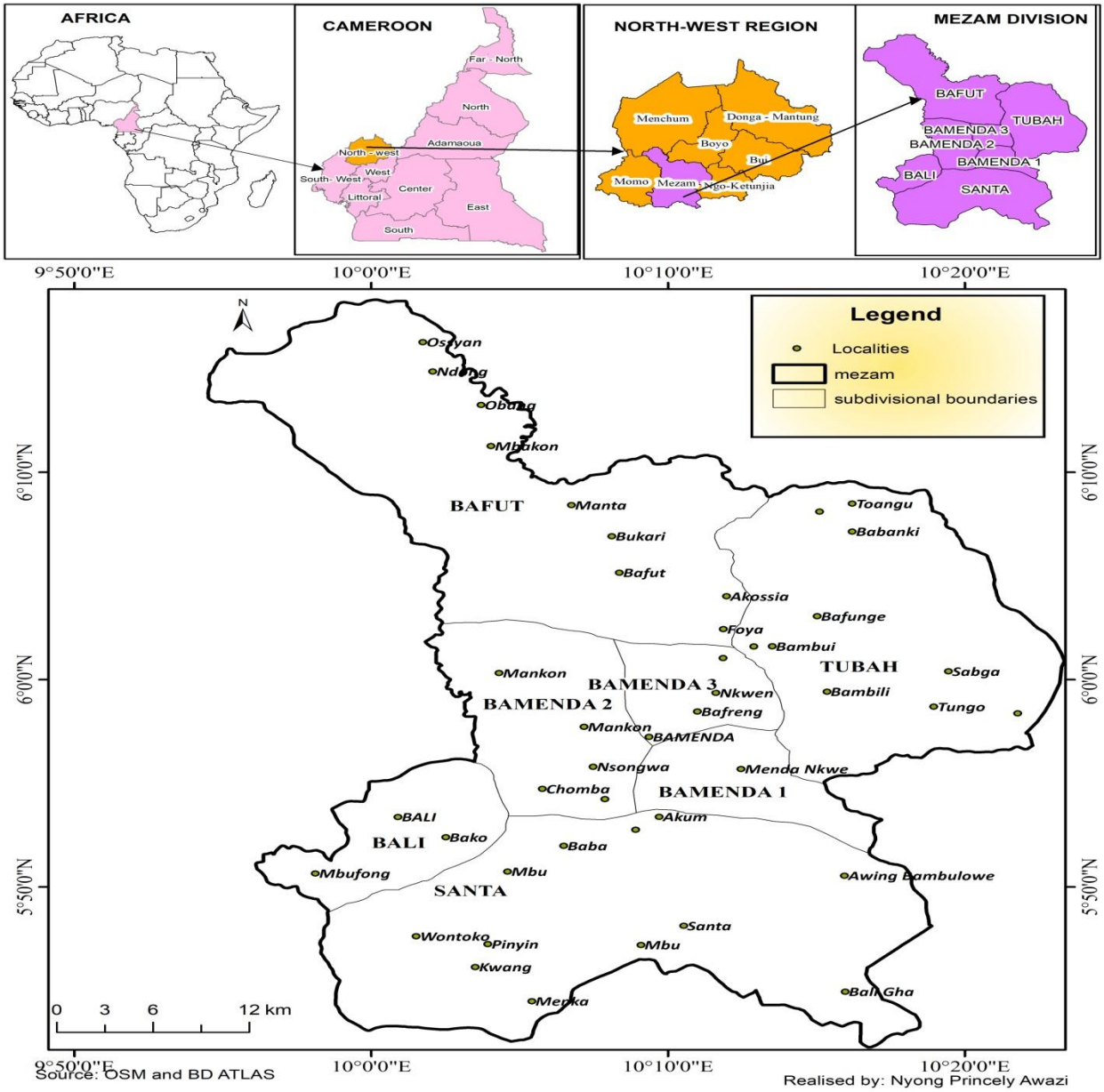

Figure 3.1: Map of the study area

The division is host to the capital of the North-West Region – Bamenda. Bamenda is a major road junction town characterized by a gentle sloping Up Station area separated from an undulating to flat Down Town area by an escarpment which is about 7 km long.

The climate is the humid tropical highland type characterized by two seasons – a rainy season and a dry season. The vegetation is mostly made up of savannah grassland interspersed with short stunted trees. The soils are ferralitic, vertisols and andosols, which are easily eroded and cannot support dense vegetation and intense agricultural activities. The main river that drains the division is River Mezam. Although the division has an urban section – especially the metropolitan city of Bamenda, most of the farming population lives in rural areas. These rural farmers practice mostly crop based farming, pure pastoralism and mixed crop livestock farming. Almost all the farmers are smallholders who practice subsistence agriculture, although surplus is usually sold to raise money for some basic necessities. Farming is highly dependent on rainfall with very few farmers practicing irrigation. The major crops grown here include food, cash and market gardening crops. The main food crops are maize (*Zea mays*), groundnuts (*Arachis hypogaea*), okra (*Abelmoschus esculentus*), beans (*Phaseolus vulgaris*), cocoyams (*Colocasia spp*), Irish potatoes (*Solanum tuberosum*), sweet potatoes (*Ipomoea batatas*), yams (*Dioscorea spp*), plantains (*Musa x paradisiacal*) and cassava (*Manihot esculenta*). The main cash crops are coffee (*Coffea arabica*), oil palms (*Elaies guineensis*), and banana (*Musa spp*). Market gardening crops include tomatoes (*Solanum lycopersicum*), cabbages (*Brassica oleracea var. capitata*), carrots (*Daucus carota subsp. Sativus*), lettuce (*Lactuca sativa*), garden huckleberry or African nightshade (*Solanum scabrum*), watermelon (*Citrullus lanatus*), and different varieties of condiments. Major fruits widely grown include avocado (*Persea americana*), guava (*Psidium guajava*), oranges (*Citrus sinensis*), grapes (*Citrus paradise*), plums (*Dacryodes edulis*), papaya (*Carica papaya*), and mangoes (*Mangifera indica*).

Mezam division has a population of about 465644 inhabitants, with a population density of 267 inhabitants per square kilometre (2001 statistics of the National Census Bureau).

3.2. Sampling procedure

A multiple-phase sampling procedure was followed in the study, as used by other scientific works (Hadgu *et al*., 2015; Kabir *et al.*, 2015; Atinkut and Mebrat, 2016; Awazi, 2016; Awazi and Tchamba, 2018; Awazi *et al.*, 2019).

At the first phase, the study area (Mezam division) was selected purposively owing to the high levels of vulnerability of its smallholder farmers to extreme weather events as reported by agricultural, environmental and livestock officials in Mezam division, North-West Region of Cameroon as well as other scientific research studies (Gur et al., 2015 and Innocent et al., 2016) carried out in the division. According to the reports of these officials as well as other scientific research studies, the presence of many smallholder farmers who depend almost exclusively on rainfall for agriculture as well as endemic poverty among farmers in the area makes the area a hot bed for high levels of vulnerability to extreme weather events.

At the second phase, the seven (07) sub-divisions (Bafut, Bali, Bamenda I, Bamenda II, Bamenda III, Santa and Tubah) (Table 3.1) found in Mezam division were grouped into four strata based on their geographical location with respect to the road junction town of Bamenda. These four strata were: the Northern flank (Bafut and Bamenda II sub-divisions), the Southern flank (Bamenda I and Santa sub-divisions), the Western flank (Bali and Bamenda II sub-divisions), and the Eastern flank (Bamenda III and Tubah sub-divisions). From these four strata, five sub-divisions were selected with the aid of agricultural extension officials. The five sub-divisions selected were Bamenda I, Bamenda II, Bamenda III, Tubah and Santa (Table 3.1). From these five sub-divisions, ten villages were selected still with the aid of agricultural extension officials. It is worth mentioning that at least one village was selected from each of these strata as follows: Bamenda I sub-division (Mendakwe village); Bamenda II sub-division (Mankon village); Bamenda III sub-division (Nkwen village); Tubah sub-division (Bambui, Bambili and Kedjom Keku villages); and Santa sub-division (Awing, Akum, Njong and Mbei villages). It is important to note that, many more villages were selected from Tubah and Santa sub-divisions owing to their essentially rural milieu which suited the study perfectly.

The third phase involved focus group discussions with smallholder farmers; and key informant interviews (KIIs) with village leaders, chiefs of agricultural posts, divisional and sub-divisional delegates in the Ministries of Agriculture and Rural Development; Environment, Protection of Nature and Sustainable Development; Livestock, Fisheries and Animal Husbandry (appendix 1, appendix 6 and appendix 8). Focus group discussions (FGDs) and key informant interviews (KIIs) were conducted in order to obtain vital information about the situation on the ground and to identify potential smallholder farmers to be sampled during the household surveys.

At the fourth phase, stratified random sampling of smallholder farmers was undertaken in the selected villages. Smallholder farmers were stratified into two groups: agroforestry practitioners and non-agroforestry practitioners. Random sampling was then conducted in both strata (agroforestry practitioners and non-agroforestry practitioners). In this light, forty (40) smallholder farmer household heads were randomly sampled in the selected villages of Mankon, Nkwen, Bambui, Bambili, and Akum; while 30 smallholder farmer household heads were sampled in the villages of Kedjom Keku, Mendakwe, Mbei-Santa, Njong-Santa and Awing. Thus, a total of 350 smallholder farmer household heads were sampled in the 10 selected villages (Table 3.2**)**. Equally, the agroforestry and non-agroforestry farm plots of smallholder farmers in the different villages were surveyed during which the different crop, livestock and tree species found in them were identified. A total of 200 agroforestry farm plots and 70 non-agroforestry farm plots of smallholder farmers were surveyed in the ten villages (Table 3.3).

Table 3.1: Farming population and number of smallholder farmers sampled in selected sub-divisions in Mezam division, North-West Region of Cameroon

Sub-division	Total population	Active population	Farming population	Number of farming families	Number of household heads sampled
Bamenda I	39501	22911	13746	2291	30
Bamenda II	265674	154091	66685	11114	40
Bamenda III	153570	89071	41820	6970	40
Tubah	67613	39216	30156	4553	110
Santa	68707	39850	32354	5392	130
Bali	38151	22128	16364	2727	-
Bafut	87567	50787	37817	6303	-
Total	**720780**	**418052**	**238942**	**39351**	**350**

Source: 2018 Annual Report of the Divisional Delegation of Agriculture and Rural Development for Mezam Division, North-West Region of Cameroon.

Table 3.2: Number of household heads sampled in the selected villages in Mezam Division, North-West Region of Cameroon

Village	Number of respondents sampled
Mankon	40
Nkwen	40
Bambui	40
Bambili	40
Kedjom Keku	30
Mendakwe	30
Mbei-Santa	30
Akum	40
Njong-Santa	30
Awing	30
Total	**350**

3.3. Vulnerability and resilience assessment procedure

The vulnerability and resilience framework proposed by the Inter-governmental Panel on Climate Change (IPCC) was adapted for this study. Following this framework, vulnerability to climate variability and change is a function of three main indicators: exposure, sensitivity and adaptive capacity (resilience).

The indicators of exposure of smallholder farming systems (agroforestry and non-agroforestry systems) to climate variability and change were variations and changes in climate parameters (temperature and rainfall) and the recurrence of extreme weather events. It was hypothesized that the greater the variations and changes in climate parameters, and the more frequently extreme weather events occur, the greater the exposure of smallholder farming systems (agroforestry and non-agroforestry systems) to climate variability and change.

The indicators of sensitivity to climate variability and change were the type of smallholder farming system practiced (agroforestry or non-agroforestry system). The main agroforestry practices of smallholder farmers in the face of climate variability and change were home gardens, home gardens with livestock, trees on croplands, trees on grazing lands, improved fallows, and coffee-based agroforestry. Meanwhile, the main non-agroforestry systems of smallholder farmers were monocultures of food and market gardening crops like maize, groundnuts, yams, cocoyams, cassava, sweet potatoes, Irish potatoes, cabbages, carrots,

tomatoes, condiments; and monocultures of cash crops like coffee and oil palms. It was hypothesized that smallholder farmers practicing agroforestry were less sensitive to climate variability and change than their counterparts who were into the non-agroforestry options.

The indicators of adaptive capacity (resilience) were social capital (gender of household head, age of household head, and household size); human capital (educational level, membership in farming groups); financial capital (household income, number of farms, access to land, access to credit); and physical capital (weather stations providing climate-related information, institutions providing extension services, markets, farm-to-market roads). It was hypothesized that as social, financial, human and physical capital increases, resilience increases. Meanwhile as social, financial, human and physical capital decreases, resilience equally decreases.

Thus, for vulnerability to reduce in the face of climate variability and change, smallholder farming systems (agroforestry and non-agroforestry systems) need to experience less exposure, have less sensitivity, and have more adaptive capacity or resilience.

3.4. Data collection procedure

Both secondary and primary data was collected for the study (Figure 3.3).

3.4.1. Secondary data collection

Secondary data mainly on past temperature and rainfall (appendix 2, appendix 3 and appendix 4) was collected from the Regional Service of Meteorology for the North-West Region (Bamenda-Station). Equally, several research papers and articles, book chapters and books related to the subject matter of the study were sourced both online and offline during the review of literature. Related studies undertaken in the North-West Region of Cameroon have used a similar data collection approach (Kimengsi et al., 2016; Azibo et al., 2016; Awazi et al., 2019).

3.4.2. Primary data collection

Qualitative and quantitative methods were employed during primary data collection in the study sites as used by other related studies conducted in the North-West Region of Cameroon (Awazi, 2016; Awazi and Tchamba, 2018; Awazi et al., 2019). Household surveys, field surveys (inventories), focus group discussions (FGDs), key informant interviews (KIIs), and

direct field observations (DFOs) were the main methods used to collect primary data. Thus, both biophysical and socio-economic primary data was collected for the study.

A large part of the primary data was collected via household surveys, using semi-structured questionnaires, with smallholder farmer household heads constituting the main sampling unit. Focus group discussions with smallholder farmers and key informant interviews (KIIs) with purposely selected resource persons in the study area provided general information to complement the data obtained through household surveys. A semi-structured interview guide approach was employed during focus group discussions and key informant interviews (KIIs) in order to capture some salient information that could be quantified and used in the study. Household surveys, focus group discussions and key informant interviews provided vital socio-economic data needed for the study.

Field inventories were also undertaken using data collection sheets for inventory of trees, crops and livestock, with agroforestry and non-agroforestry plots constituting the main sampling units. Field inventories of agroforestry and non-agroforestry plots, as well as direct field observations were undertaken in the study sites in order to ascertain the truthfulness of the information gotten from household surveys, focus group discussions and key informant interviews (KIIs). Field surveys (inventories of agroforestry and non-agroforestry plots) provided vital biophysical primary data necessary for the study.

3.4.2.1. Sample frame, study population and sample size

For this study, the sample frame consisted of ten villages in Mezam Division, North-West Region of Cameroon: Mankon (Latitude $6^{o}00$'N; Longitude $10^{o}06$'E; Altitude 1200 metres above sea level - masl), Nkwen (Lat. $5^{o}98$'N; Long. $10^{o}21$'E; Alt. 1350masl), Bambui (Lat. $6^{o}02$'N; Long.$10^{o}21$'E; Alt. 1250masl), Bambili (Lat. $6^{o}01$'N; Long. $10^{o}27$'E; Alt. 1500masl), Kedjom Keku (Lat. $5^{o}97$'N; Long. $10^{o}31$'E; Alt. 1350 masl), Mendakwe (Lat. $5^{o}92$'N; Long. $10^{o}20$'E; Alt. 1900 masl), Mbei-Santa (Lat. $5^{o}78$'N; Long. $10^{o}14$'E; Alt. 1700 masl), Akum (Lat. $5^{o}88$'N; Long. $10^{o}16$'E; Alt. 1900 masl), Njong-Santa (Lat. $5^{o}79$'N; Long. $10^{o}17$'E; Alt. 1700 masl), and Awing (Lat. $5^{o}83$'N; Long. $10^{o}25$'E, Alt. 1650 masl). With the help of agricultural extension officials, these villages were selected taking into account the socio-economic, agro-ecological and environmental attributes of the study area. A household survey was then undertaken in the selected sites using semi-structured questionnaires. Smallholder farmer household heads living in the selected villages constituted the study

population. The study population was sampled in such a way as to ensure an adequate sample size (≥ 30) for each of the selected villages. According to Bhandari (2009), a general rule of simple and stratified random sampling is that a minimum of 30 persons should be surveyed in a given study site in order to capture some vital information that can be used for analysis. It was in this light that a minimum of 30 smallholder farmer household heads was sampled in each of the selected villages.

3.4.2.2. Questionnaire design for household survey

The study made use of the semi-structured questionnaire approach in order to capture both qualitative and quantitative information from smallholder farmers, as used by other related studies (Tabi *et al.,* 2012; Awazi and Tchamba, 2018; Awazi *et al.,* 2019). Both open ended and close ended questions were incorporated in order to acquire sufficient information from the respondents (smallholder farmer household heads). The questions were designed to provide answers to each of the specific objectives of the study (appendix 5). The questionnaire was sub-divided into five sections. The first section looked at the demographic and socio-economic attributes of the respondents. These attributes included gender, age, education, marital status, household size, annual family income, and number of farms. The second section laid emphasis on the perceptions of smallholder farmers pertaining to climate variability and change as well as their vulnerability to climate variability and change. The third section focused on the different agroforestry practices of smallholder farmers in the face of climate variability and change. The fourth section focused on the role of these agroforestry practices in reducing smallholder farmers' vulnerability to climate variability and change. The fifth and last section looked at the contributions of agroforestry practices to smallholder farmers' resilience in the face of climate variability and change. Thus, the questions for the last four sections (sections 2, 3 4 and 5) were tailored to attain the four specific objectives of the study (appendix 5).

In order to ensure that the questions posed on the questionnaire were good enough, the questionnaire was tested with non-respondents outside the sample frame (study area) – in Mbengwi sub-division, North-West Region of Cameroon. The reason for the pretesting was to gauge smallholder farmers' comprehension and response to each of the questions posed. The responses from the pretesting helped the principal investigator and his team to refine and restructure the final questionnaire to make it more comprehensible to smallholder farmers' in

the selected villages. It is worth mentioning that, during household surveys, the questions were translated into "Pidgin" to ease comprehension and response by the respondents.

Household surveys were conducted during the months of December 2018 and January 2019 in the ten selected villages. The survey was conducted by the principal investigator and some team members, with some assistance from the chiefs of agricultural posts found in each of the ten selected villages. Mainly the face-to-face interview approach was employed during the administering of questionnaires in all the ten selected villages (appendix 9). The household surveys were conducted in the months of December and January because it was the dry season, which facilitated movements to the different study sites; and considering that it was the off-season for farming, which meant that most farmers were at home, thus facilitating the household survey proper.

3.4.2.3. Inventory of crop, livestock and tree species on smallholder farmers' agroforestry and non-agroforestry plots

In order to identify the different crop, livestock and tree species integrated in smallholder farmers' agroforestry and non-agroforestry plots, inventories were conducted in May and June 2018. These inventories were conducted by the principal investigator with the help of some team members (including a botanist from the National Forests Agency – ANAFOR, and an expert from the divisional delegation of livestock, fisheries and animal husbandry). The inventories were conducted in order to acquire vital biophysical data needed for the study. Field inventories were undertaken in the months of May and June because it was the rainy season, which was the peak period of growth for most crops, and trees/shrubs. Thus, it was relatively easier to identify the different crops and trees/shrubs on smallholder farmers' agroforestry and non-agroforestry farm plots at this time.

Table 3.3: Agroforestry plots of smallholder farmers surveyed

Agroforestry practices	Number of plots surveyed (n)	Number of plots surveyed (%)
Home garden with livestock	35	17.5
Home garden	30	15
Trees on croplands	30	15
Live fences/hedges	30	15
Taungya	20	10
Trees on grazing lands	15	7.5
Improved fallows	10	5
Coffee-based agroforestry	25	12.5
Others (entomoforestry, aquaforestry)	5	2.5
Total	**200**	**100**

Two hundred (200) smallholder farmers' agroforestry plots (appendix 7 and appendix 10) and seventy (70) smallholder farmers' non-agroforestry plots (appendix 11) were surveyed in the 10 villages under study (Tables 3.3 and 3.4). The geographical coordinates (latitude, longitude and altitude) of each surveyed plot were taken using Garmin GPS 60, and used to establish a map showing the distribution of the different plots (Figure 3.2).

Table 3.4: Non-agroforestry (monoculture) plots of smallholder farmers surveyed

Speculations	**Number of plots surveyed (n)**	**Number of plots surveyed (%)**
Market gardening crops only	20	28.57
Cash crops only	20	28.57
Food crops only	25	35.71
Livestock only	5	7.14
Total	**70**	**100**

In smallholder farmers' agroforestry plots, inventories were conducted to identify crops, livestock and trees in the different agroforestry systems/practices of smallholder farmers which included home gardens with livestock, home gardens, trees on croplands, trees on grazing lands, live fences/hedges, Taungya, coffee-based agroforestry, improved fallows, windbreaks, entomoforestry, and aquaforestry.

Meanwhile in smallholder farmers' non-agroforestry plots, inventories were conducted to identify crops and livestock within the different speculations including market gardening crops, cash crops, food crops and livestock.

Since most (over 95%) of the smallholder farmers' agroforestry and non-agroforestry plots were less than half a hectare (0.5 hectare), the inventory was conducted directly without any measurements of the plots. The plant species were identified with the help of a botanist from ANAFOR – northwest regional service, while the livestock species were identified with the help of an expert from the divisional delegation of livestock, fisheries and animal husbandry for Mezam Division, North-West Region of Cameroon.

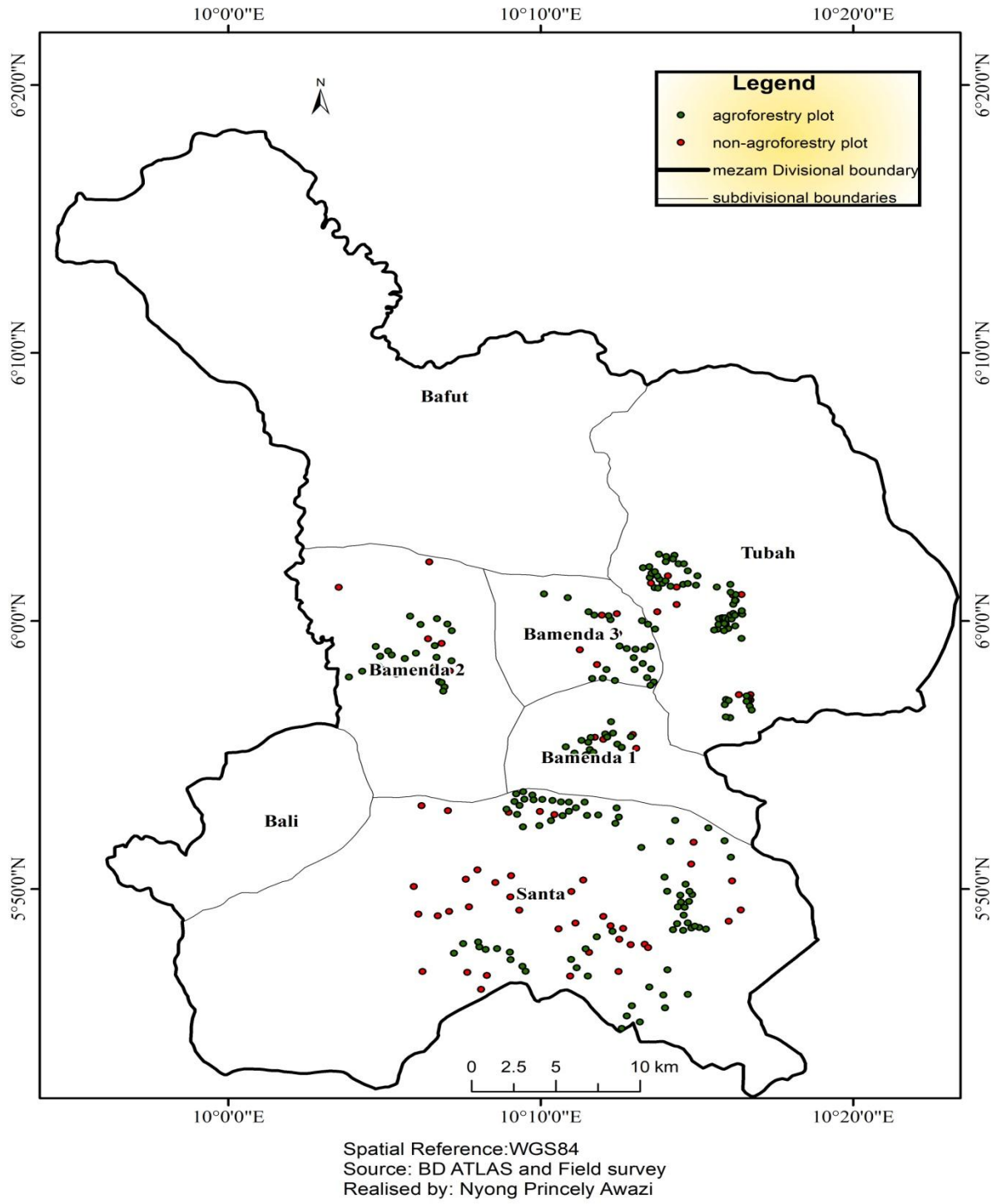

Figure 3.2: Map showing distribution of agroforestry and non-agroforestry plots surveyed

3.4.2.4. Key informant interviews

Different studies have used key informant interviews (KIIs) to collect qualitative data from various studied populations (Bhandari, 2009; Awazi, 2016; Awazi and Tchamba, 2018; Awazi *et al.,* 2019). This study followed the same path by using key informant interviews

(KIIs) to collect primary data in the study area (appendix 1 and appendix 6). Thirty key informants were selected for the study in five of the seven districts that made up the study area. The key informant interviews (KIIs) focused on aspects like perception of climate variability and change, indicators of climate variability and change, effects of climate variability and change, vulnerability and resilience to climate variability and change, agroforestry practices and systems, products and services of agroforestry practices and systems, contribution of agroforestry practices/systems to the attenuation of smallholder farmers' vulnerability to climate variability and change; and role of agroforestry practices/systems to the enhancement of smallholder farmers' resilience in the face of climate variability and change. The interview was coordinated by the principal investigator using a checklist or interview guide (appendix 6).

Mainly resource persons were interviewed: delegates and sub-delegates in the divisional and sub-divisional delegations of agriculture and rural development; livestock, fisheries and animal husbandry; forestry and wildlife; environment, protection of nature and sustainable development; chiefs of agricultural posts in the study sites, traditional leaders (chiefs or Fons, Sarkis and Ardos); and heads of farmers' groups (appendix 1).

3.4.2.5. Focus group discussion

Focus group discussion (FGD) is an exploratory research tool used extensively by researchers to generate qualitative data and triangulate findings. It is a qualitative study method that requires a small homogeneous group of experienced people to discuss a study topic. In this study, focus group discussion was used to get information from smallholder farmers in the study sites pertaining to extreme weather events, causes of vulnerability, agroforestry practices and systems, and role of agroforestry systems to vulnerability attenuation and resilience enhancement in the face of climate variability and change. The discussion was led by the principal investigator with the help of a drafted interview guide or checklist (appendix 8). Mostly experienced persons of both genders were invited to participate in the focus group discussions. The participants provided necessary information based on their recall of past and present experiences on the subject matter of the study. Five focus group discussions were conducted in the five selected sub-divisions in Mezam division, North-West Region of Cameroon.

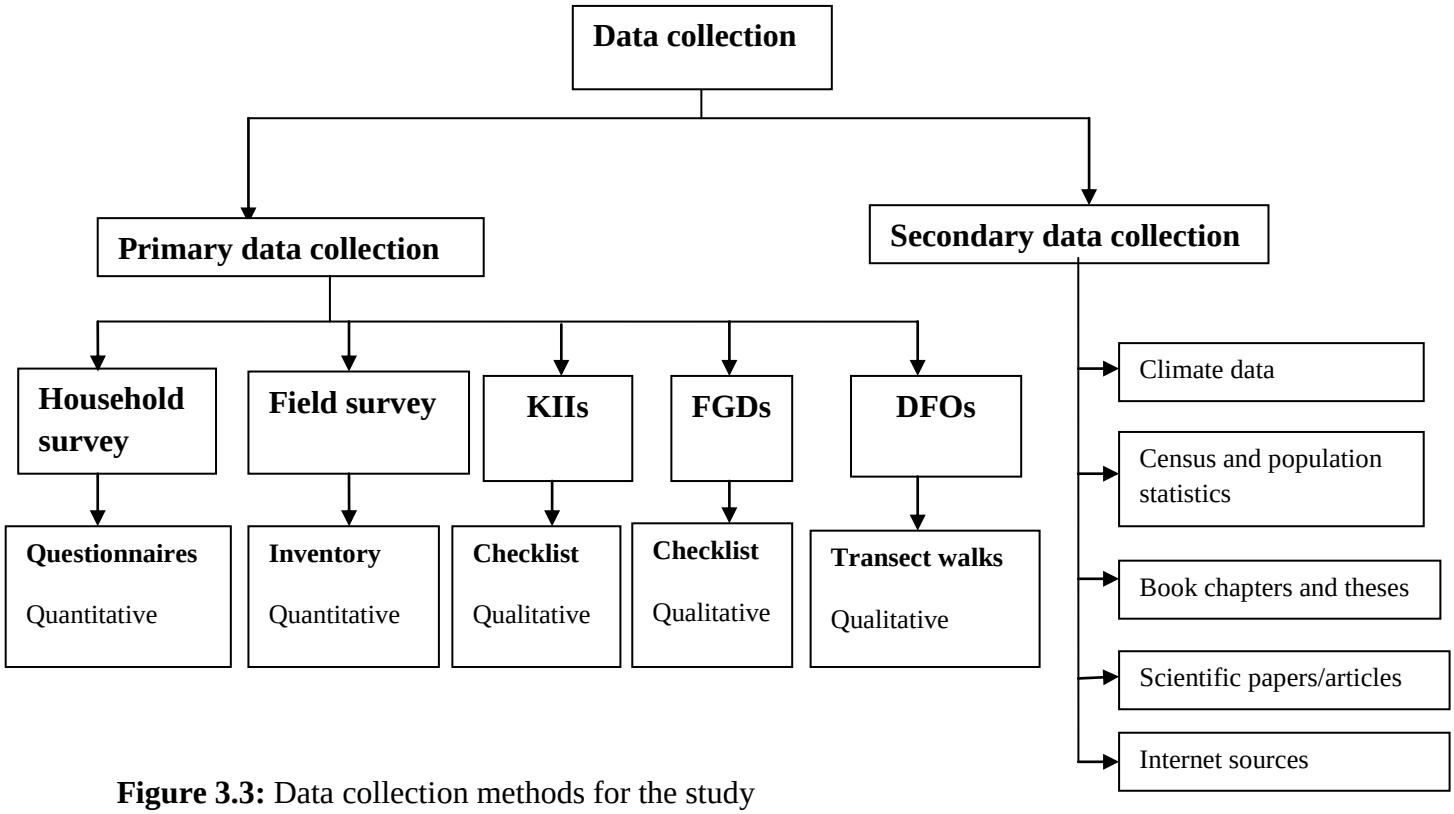

Figure 3.3: Data collection methods for the study

Source: Awazi (2019)

3.4.2.6. Assessing drivers of smallholder farmers' vulnerability to climate variability and change

Different studies have assessed the drivers of smallholder farmers' vulnerability to climate variability and change in Cameroon, Africa and the World, using different methodological approaches. For this study, both farmers' perceptions obtained through household surveys and climate data obtained from weather stations in the North-West Region of Cameroon were indispensable. Pertaining to smallholder farmers' perceptions; during household surveys, household heads were asked to state what they perceived as the causes or sources of their vulnerability in the face of climate variability and change. All the respondents generally cited more than one cause or source of their vulnerability in the face of climate variability and change.

Smallholder farmers' perceptions of variations in climate parameters in particular were taken into consideration. Smallholder farmer household heads were asked to rate the variations they have experienced in climate elements like rainfall, temperature, sunshine and storms, in recent years. Rainfall patterns were rated in terms of total amount of rainfall and rainfall consistency (late or early onset of rain, late or early cessation of rain). Smallholder farmers rated total amount of rainfall on the five point likert scale of: increased a lot, increased,

stayed the same, decreased, and decreased a lot. Meanwhile rainfall consistency was rated on the five point likert scale of: much more variable, variable, stayed the same, less variable, and much less variable. Temperature on its part was rated on the five point likert scale of: much hotter, hotter, stayed the same, cooler, and much cooler. Sunshine and storms (winds) were rated on the five point likert scale of: increased a lot, increased, stayed the same, decreased, and decreased a lot. To reconcile farmers' perceptions of variations in climate parameters with actual climate data, data was collected from weather stations in the North-West Region of Cameroon. Other related research studies undertaken across Cameroon, Africa and the tropics have used a similar data collection approach (Tabi *et al.*, 2012; Harvey *et al.,* 2014; Rurinda, 2014; Kirui *et al.,* 2015; Atinkut and Mebrat, 2016 ; Awazi, 2016; Awazi *et al.*, 2019).

Smallholder farmers' perceptions as well as climate data collected from weather stations in the North-West Region of Cameroon were then coded and imputed into SPSS version 20.0 for descriptive and inferential statistical analysis.

3.4.2.7. Characterizing smallholder farmers' agroforestry practices in the face of climate variability and change

There exists scholarship (although few) which have used different data collection methods to characterize smallholder farmers' agroforestry practices in the face of climate variability and change. For this study, household and field surveys were conducted. During the household surveys, smallholder farmer household heads practicing agroforestry were asked to identify the different agroforestry practices they practiced in the face of climate variability and change. Smallholder farmer household heads who practiced agroforestry in the face of climate variability and change usually took to a combination of agroforestry practices simultaneously. The different agroforestry practices cited by smallholder farmer household heads were then classified under three main agroforestry systems: agrosilvicultural, silvopastoral and agrosilvopastoral agroforestry systems. Information gotten from household surveys was complemented with that gotten from field inventories of smallholder farmers' agroforestry plots. Both the agroforestry practices identified by smallholder farmer household heads and the classified agroforestry practices (agroforestry systems) were then coded and imputed into SPSS version 20.0 for descriptive and inferential statistical analysis. Little or no research has been done that applies this data collection procedure to characterize smallholder farmers' agroforestry practices faced with climate variability and change. Most studies

conducted across Africa have applied other data collection approaches which are mostly qualitative or based on a review of previous literature (Bishaw *et al.*, 2013; Atangana *et al.*, 2013; Negawo and Beyene, 2017).

3.4.2.8. Examining the contribution of agroforestry practices to vulnerability reduction and resilience enhancement to climate variability and change in smallholder farming systems

Different data collection methods have been used by various studies to examine the contribution of agroforestry practices to vulnerability reduction and resilience enhancement to climate variability and change in smallholder farming systems. For this study, household surveys were conducted during which smallholder farmers' perceptions were obtained. During the household surveys, smallholder farmers practicing agroforestry were asked if they felt vulnerable or not; and resilient or not to climate variability and change. Smallholder agroforestry practitioners were equally asked to cite the different products and services they derived from the practice of agroforestry and how these products and services affected their vulnerability and resilience to climate variability and change. Data collected through household surveys was complemented with information gotten from field inventories, key informants, focus group discussions and direct field observations. The responses of smallholder farmers were then coded and imputed into SPSS version 20.0 for descriptive and inferential statistical analysis. Few or no studies have applied the data collection method explained here, to assess the contribution of agroforestry to the reduction of vulnerability and the enhancement of resilience faced with climate variability and change. Most studies have been based entirely on a qualitative or review of literature approach (Negawo and Beyene, 2017; Mkonda and He, 2017).

3.5. Data analysis procedure

Statistical analysis of the quantitative data obtained from household and field surveys was run on the Statistical Package for Social Sciences (SPSS) version 20.0, Microsoft Excel 2007, and STATA 13.0. Both descriptive and inferential statistics were used in the study. Smallholder farmers' perceptions of climate variability and change; causes or sources of vulnerability to climate variability and change; as well as agroforestry practices were presented using descriptive statistics (percentages indices and charts). The study equally made use of different inferential statistics (t-test, chi-square, correlation, Kruskall Wallis (H)

test, binary logistic regression and multinomial logistic regression models) to assess the causal and non-causal relationship between the hypothesized dependent and independent variables of the study.

The independent samples t-test (Equation 3.1) and chi-square test (Equation 3.2) were used to determine if there was a significant non-causal relationship between smallholder farmers' vulnerability and resilience to climate variability and change, and the hypothesized continuous and discontinuous explanatory variables of the study respectively.

$$\textbf{t-test} = \frac{\bar{Y}-\bar{X}}{\mathrm{Sp}\sqrt{\frac{(m+n)}{mn}}} \quad \text{where } S_p = \sqrt{\frac{\sum(X-\bar{X})^2+\sum(Y-\bar{Y})^2}{m+n-2}} \qquad \text{Equation 3.1}$$

Where:
$\bar{Y}$: is the mean of variable Y;

$\bar{X}$: is the mean of variable X;

m: is the sample size of variable X;

n: is the sample size of variable Y;

S_p: is the pooled estimate of the common standard deviation of both variable X and Y

In the case of a 2x2 contingency table which is what has been used in this study, the formula used by SPSS to compute Chi-square (X^2) is as follows:

$$\boldsymbol{X^2} = \frac{(\mathbf{a.d-b.c})^{\mathbf{2}}.\mathbf{N}}{(\mathbf{a+c}).(\mathbf{b+d}).(\mathbf{a+b}).(\mathbf{c+d})} \qquad \text{Equation 3.2}$$

Where for example:

a: is frequency of agroforestry practitioners who are resilient/vulnerable to CVC.

b: is frequency of agroforestry practitioners who are not resilient/not vulnerable to CVC.

c: is frequency of non-agroforestry practitioners who are resilient/vulnerable to CVC.

d: is frequency of non-agroforestry practitioners who are not resilient/not vulnerable to CVC.

N: is the total frequency of all observations.

As a rule of thumb, the normality of the continuous variables was tested using: histogram with normal curve, Probability Plot (PP) and Qauntile Quantile (QQ) diagrams, and most importantly the one sample Kolmogorov−Smirnov test, before choosing the suitable statistic for the analysis.

In the case of the independent samples t-test, a pre-test known as the Levene's test for the equality of variances was run before reading the t-test results. The hypothesis for the Levene's test goes thus:

H_0: Equal variance assumed

Ha: Equal variance not assumed

If the F-value of the Levene's pre-test is statistically significant, it means that Ha is accepted, implying that equal variance is not assumed. But if on the contrary the F-value of the Levene's pre-test is not statistically significant, it means H_0 is accepted, implying that equal variance is assumed. Hence, the results of the independent samples t-test are read depending on whether equal variance is assumed or equal variance is not assumed.

The Spearman rank correlation (Spearman rho) (Equation 3.3) was run to determine the relationship between the practice of agroforestry and smallholder farmers' vulnerability and resilience to climate variability and change. The Spearman rho which is the non-parametric equivalent of the Pearson correlation coefficient is presented as follows:

$$\textbf{Spearman rho} = 1 - \frac{6\Sigma(di)^2}{n(n^2-1)} \qquad \text{Equation 3.3}$$

Where:

n: is the numbers of pairs of values of variables X and Y;

di: is the difference obtained from subtracting the rank of Yi from the rank of Xi;

$\Sigma(di)^2$: is the sum of the squared values of di.

The Kruskal-Wallis test (H-test) (Equation 3.4) was run to test whether there was a significant variation in smallholder farmers' vulnerability and resilience across different locations (villages). The Kruskall Wallis (H) test statistic which is the non-parametric equivalent of the ANOVA test is presented as follows:

$$H = \frac{12}{N(N+1)}\left[\frac{R_1^2}{n_1} + \cdots \ldots + \frac{R_k^2}{n_k}\right] - 3(N+1) \qquad \text{Equation 3.4}$$

Where:

N = Total number of cases;

n = Number of cases in a given sample;

R_i = Rank for a given sample.

This is one of the first studies undertaken across Cameroon, Africa and the tropics, to use the inferential statistics of t-test, chi-square, correlation, and the H-test to analyze the non-causal relationship that exists between smallholder farmers' vulnerability and resilience to climate variability and change, and different agroforestry practices/agroforestry systems. Most studies have adopted qualitative analysis approaches.

The binary logistic (BNL) regression model (Equation 3.5) on its part was used to examine the causal relationship between smallholder farmers' vulnerability and resilience to climate variability and change, and several hypothesized continuous and discontinuous explanatory variables (Table 3.5). The binary logistic regression model predicts the log odds of having made one decision or the other. This model therefore permits the analysis of decisions across two categories:

$$\text{BNL} = \ln\left(\frac{\hat{Y}}{1-\hat{Y}}\right) = \propto + \beta X \qquad \text{Equation 3.5}$$

Where

$\hat{Y}$: is the predicted probability of the event;

$1 - \hat{Y}$: is the predicted probability of the other decision;

X: is the independent or explanatory variable.

Before running the binary logistic regression model, the Box-Tidwell Test was used to test if the relationship between the continuous predictors and the logit (log odds) was linear. This assumption was tested by including in the model, interactions between the continuous predictors and their logs. The aforementioned assumption and the binary logistic (BNL) regression proper were done on SPSS version 20.0.

After an in-depth literature review, no study conducted across Cameroon, Africa and the tropics was found to have used the binary logistic regression model to analyze the causal relationship between smallholder farmers' vulnerability and resilience to climate variability and change; and most especially the contribution of agroforestry practices/systems towards reducing vulnerability and enhancing resilience to climate variability and change. Most studies that used the binary logistic (BNL) regression model focused mainly on the drivers of farmers' adaptation to climate variability and change (Di Falcao *et al.*, 2011; Awazi, 2016; Awazi and Tchamba, 2018).

The multinomial logistic (MNL) regression model (Equation 3.6) was equally used to determine the causal relationship between smallholder farmers' choice of agroforestry systems (multinomial dependent variable) with respect to various hypothesized continuous and discontinuous explanatory variables (Table 3.5). The dependent variable for the model had three main categories: agrosilvicultural system, silvopastoral system and the agrosilvopastoral system. The fourth category (no agroforestry) was the reference category. Following Greene (2003), Koch (2010) and Wooldridge (2013), the multinomial logistic (MNL) model permits the analysis of multiple choice problems. According to Deressa et al (2009), the multinomial logistic (MNL) regression model permits the analysis of decisions across more than two categories, enabling the determination of choice probabilities and is equally simple to compute. This model has response probabilities.

$$P(y = j / x) = \frac{\exp(x\beta_j)}{1 + \sum_{k=1}^{j} \exp(x\beta_k)}, j = 1, \ldots\ldots\ldots J \qquad \text{Equation 3.6}$$

Where:

y: is a random variable (agroforestry systems) with the values (1,2,.....J);

j: is a positive integer;

x: is a set of conditioning variables (socio-economic, institutional and environmental factors);

βj: is K × 1.

The running of the multinomial logistic (MNL) regression model proper was done on SPSS version 20.0. But before running the actual model estimate, the Hausman Specification test was run on STATA version 13 in order to check the validity of the Independence of Irrelevant Alternatives (IIA) assumption. The test result failed to reject the null hypothesis of the independence of the different agroforestry systems under consideration. This implies that the application of the multinomial logistic (MNL) specification was appropriate to model the determinants of smallholder farmers' choice of agroforestry systems faced with climate variability and change.

Following an in-depth review of literature, it was found that, this one of the first studies undertaken in Cameroon, Africa and the tropics that makes use of the multinomial logistic regression model to analyze the determinants of smallholder farmers' choice of agroforestry systems faced with climate variability and change. Most studies conducted across Cameroon, Africa and the tropics have rather used the multinomial logistic (MNL) regression model to

analyze the determinants of smallholder farmers' adaptation choices or options faced with climate variability and change (Temesgen *et al.*, 2008; Tabi *et al.*, 2012; Temesgen *et al.*, 2014; Tesfay, 2014; Atinkut and Mebrat, 2016 ; Awazi, 2016 ; Awazi *et al.*, 2019).

- **Variables for the study**

This study had five main dependent variables (vulnerability, resilience, practice of agroforestry, agroforestry systems and villages) and twenty (20) independent variables (Tables 3.5, 3.6 and 3.7).

Table 3.5: Dependent and independent variables of the study

Dependent variables	Independent variables
Vulnerability	Number of farms
Resilience	Household size
Practice of agroforestry	Age of household head
Agroforestry systems	Annual income of household
Villages	Educational level
	Gender of household head
	Practice of agroforestry
	Vulnerability to CVC
	Access to information
	Access to credit facilities
	Access to land
	Access to extension services
	Home garden with animals
	Home garden
	Trees on croplands
	Live fences/hedges
	Trees on grazing lands
	Coffee-based agroforestry
	Taungya
	Improved fallows

Table 3.6: Description of dependent variables of the study

Dependent variables	Description
Vulnerability	Dummy, takes value of 1 if vulnerable and, 0 otherwise
Resilience	Dummy, takes value of 1 if resilient and, 0 otherwise
Practice of agroforestry	Dummy, takes value of 1 if agroforestry is practiced and, 0 otherwise
Agroforestry systems	Dummy, takes value of 1 if agrosilvicultural, 2 if silvopastoral, and 3 if agrosilvopastoral

Table 3.7: Description of independent variables of the study

Independent variables	Description
Number of farms	Continuous
Household size	Continuous
Age of household head	Continuous
Household income	Continuous
Educational level	Dummy, takes value of 0 for no formal education, 1 for primary, 2 for secondary, 3 for high schools and 4 for tertiary
Gender of household head	Dummy, takes value of 1 if male and, 0 otherwise
Practice of agroforestry	Dummy, takes value of 1 if Yes and, 0 otherwise
Vulnerability to CVC	Dummy, takes value of 1 if Yes and, 0 otherwise
Access to information	Dummy, takes value of 1 if Yes and, 0 otherwise
Access to credit facilities	Dummy, takes value of 1 if Yes and, 0 otherwise
Access to land	Dummy, takes value of 1 if Yes and, 0 otherwise
Access to extension services	Dummy, takes value of 1 if Yes and, 0 otherwise
Home garden with livestock	Dummy, takes value of 1 if Yes and, 0 otherwise
Home garden	Dummy, takes value of 1 if Yes and, 0 otherwise
Trees on croplands	Dummy, takes value of 1 if Yes and, 0 otherwise
Live fences/hedges	Dummy, takes value of 1 if Yes and, 0 otherwise
Trees on grazing lands	Dummy, takes value of 1 if Yes and, 0 otherwise
Coffee-based agroforestry	Dummy, takes value of 1 if Yes and, 0 otherwise
Taungya	Dummy, takes value of 1 if Yes and, 0 otherwise
Improved fallows	Dummy, takes value of 1 if Yes and, 0 otherwise

From tables 3.5, 3.6 and 3.7 above, it is noticed that the dependent and independent variables of the study were mostly qualitative or discontinuous in nature. This explains why most of the statistical analysis was done using non-parametric tests and non-linear or discrete regression models like the binomial and multinomial logistic regression models.

3.6. Survey limitations

The study was not without limitations. The limitations of the study were:

First and foremost, the study was carried out in the crisis hit North-West Region of Cameroon (specifically Mezam Division), which made it difficult to access all the sub-divisions found in the study area. Although the study was to be undertaken in all the seven (07) sub-divisions constituting Mezam division, the survey proper was carried out in just five (05) of the seven (07) sub-divisions owing to the inability to access two sub-divisions (Bafut and Bali) affected by recurrent skirmishes. It would have been better if the study was conducted at peace times, and in all of the seven sub-divisions that make up Mezam division.

Secondly, the study was conducted in Mezam division which is one of the most urban divisions in the North-West Region of Cameroon. It would have been better for the study to

be carried out in an area characterized by a predominantly rural population (with many smallholder farmers). It must be said that this study was initially scheduled to be undertaken in Boyo division, North-West Region of Cameroon (owing to its predominantly rural population and the existence of diverse agroforestry practices), but the violence and recurrent skirmishes in the division forced the study to be moved to Mezam division which was the only relatively peaceful division in the entire North-West Region of Cameroon at the time of the study.

Lastly, owing to financial and time constraints, the sample size was relatively small. Out of the about 39351 farming families in entire Mezam division, 350 smallholder farmer household heads were surveyed. And out of the many smallholder farmers' agroforestry and non-agroforestry plots, 200 agroforestry plots and 70 non-agroforestry plots were surveyed. Although sampling was done taking into consideration the socio-economic, agro-ecological and environmental characteristics of the study area, it must be admitted that the sample size was relatively small. It could have been better if a larger number of smallholder farmer household heads and smallholder farmers' agroforestry and non-agroforestry plots were surveyed.

However, it must be acknowledged that although these difficulties were a real strain on the study, they did not have a major impact on the survey itself or the data collected. Hence, the findings of this study are novel, valid and relevant, and paint a state of the art picture of the situation of smallholder farmers' vulnerability and resilience to climate variability and change, and the contributions of agroforestry practices towards the attenuation of vulnerability and the enhancement of resilience of smallholder farmers to climate variability and change.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1. RESULTS

4.1.1. Drivers of smallholder farmers' vulnerability to climate variability and change

4.1.1.1. Variability and change in climate parameters

4.1.1.1.1. Temperature

Annual mean temperature has been varying tremendously across the years from 1961 to 2018. The annual mean temperature was most especially high between the years 1961-1965, 1986-1990, 1991-1995, 1996-2000, 2006-2010, 2011-2015 and 2016-2018 with annual mean temperatures of 20.12^{o}C, 19.74^{o}C, 19.98^{o}C, 19.77^{o}C, 20.28^{o}C, 20.43^{o}C and 20.88^{o}C respectively (Figure 4.1).

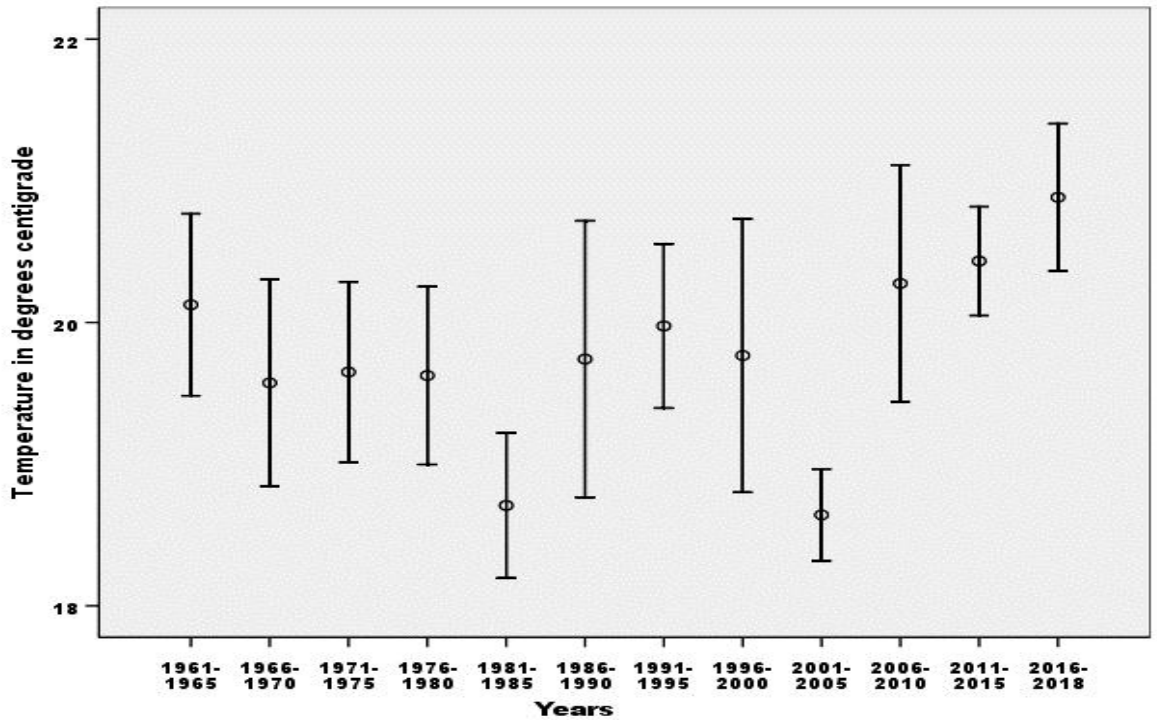

Figure 4.1: Annual mean temperature variation 1961-2018

Meanwhile the lowest annual mean temperatures were recorded in the years 1966-1970, 1971-1975, 1976-1980, 1981-1985 and 2001-2005 with annual mean temperatures of 19.57^{o}C, 19.65^{o}C, 19.62^{o}C, 18.71^{o}C and 18.64^{o}C respectively. The highest annual mean

temperature was 20.88^{o}C, recorded between 2016-2018 while the lowest annual mean temperature was 18.64^{o}C recorded between 2001-2005 (Figure 4.1). Thus, annual mean temperature has experienced significant variations in the North-West Region of Cameroon in the past five decades.

From temperature anomalies, it was found that from 1961-2018, many more years experienced an increase in temperature than a decrease. Temperature increases were most especially noticed in the years 1961-1965, 1986-1990, 1991-1995, 1996-2000, 2006-2010, 2011-2015 and 2016-2018 with positive temperature anomalies of 0.12^{o}C, 0.12^{o}C, 0.30^{o}C, 0.60^{o}C, 0.26^{o}C, 0.60^{o}C and 1.10^{o}C respectively (Figure 4.2).

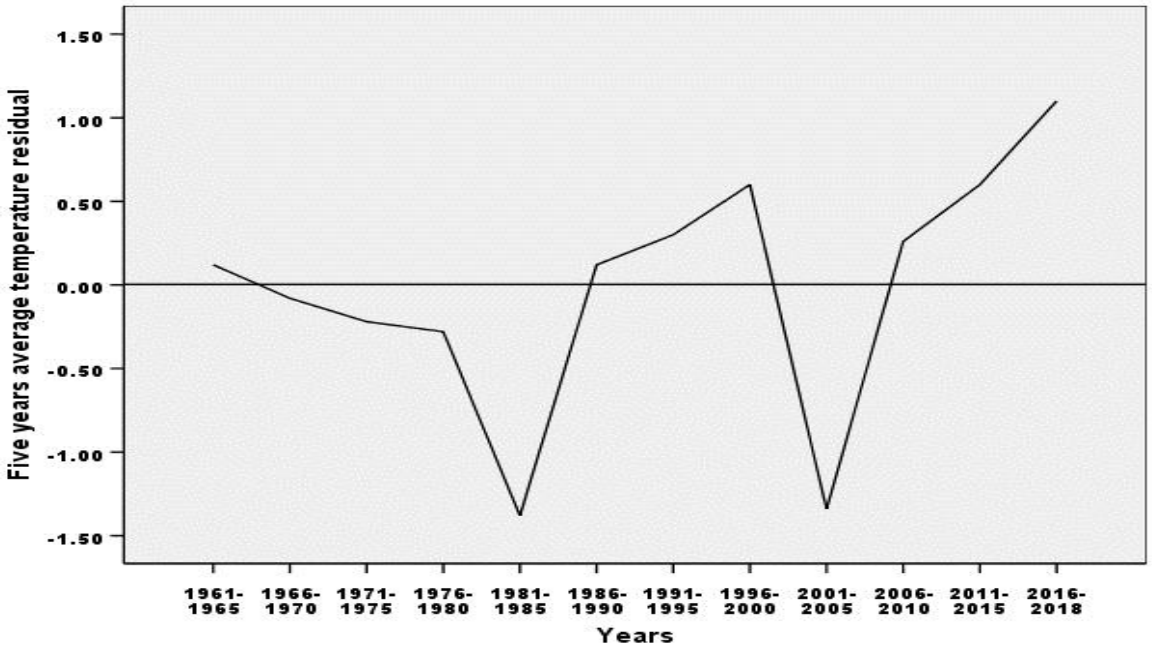

Figure 4.2: Annual temperature residuals 1961-2018

On the contrary, the years 1966-1970, 1971-1975, 1976-1980, 1981-1985 and 2001-2005 were characterized by negative temperature anomalies of -0.08^{o}C, -0.22^{o}C, -0.28^{o}C, -1.38^{o}C, and -1.34^{o}C respectively. The highest positive temperature anomaly (1.10^{o}C) was recorded in the years 2016-2018 while the highest negative temperature anomaly (-1.38^{o}C) was recorded in the years 1981-1985 (Figure 4.2). Therefore, temperature extremes have been the norm in the North-West Region of Cameroon in the past five decades.

4.1.1.1.2. Rainfall

Annual average rainfall has equally varied enormously between the years 1961 to 2018 with many more years experiencing a lesser amount of rainfall. The years 1961-1965, 1966-1970,

1976-1980, 1981-1985, and 2006-2010 were characterized by high annual average rainfall of 215.49mm, 234.07mm, 204.68mm, 205.08mm, and 194.78mm respectively (Figure 4.3). Meanwhile annual average rainfall was low between the years 1971-1975, 1986-1990, 1991-1995, 1996-2000, 2001-2005, 2011-2015, and 2016-2018 with annual average rainfall amounts of 177.48mm, 185.82mm, 168.74mm, 187.24mm, 188.9mm, 184.11mm, and 150.81mm respectively. Therefore, annual average rainfall was highest between the years 1966-1970 with 234.07mm, and lowest between the years 2016-2018 with 150.81mm (Figure 4.3). Thus, annual average rainfall in the North-West Region of Cameroon has been fluctuating significantly in the past five decades.

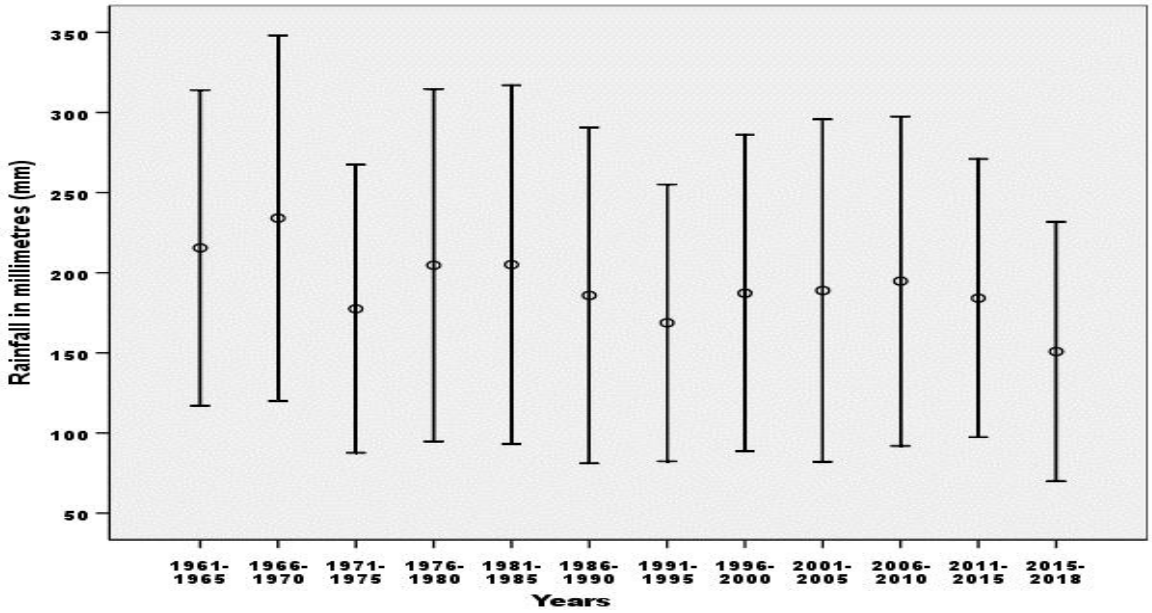

Figure 4.3: Annual average rainfall variation 1961-2018

From the computation of rainfall residuals, it was found that between the years 1961-2018, many more years had negative residuals than positive. The years characterized by positive rainfall residuals were 1961-1965, 1966-1970, 1976-1980 , 1981-1985, and 2006-2010 with rainfall anomalies of 288.7mm, 511.6mm, 158.9mm, 163.5mm and 40.1mm respectively (Figure 4.4). While the years 1971-1975, 1986-1990, 1991-1995, 1996-2000, 2001-2005, 2011-2015 and 2016-2018 were characterized by negative rainfall anomalies of -167.4mm, -67.3mm, -272.3mm, -50.3mm, -30.4mm, -87.9mm, and -487.5mm respectively. The highest positive rainfall anomaly was recorded in the years 1966-1970 with 511.6mm while the highest negative rainfall anomaly was recorded in the years 2016-2018 with -487.5mm. Thus, rainfall in the North-West Region of Cameroon has experienced significant variations and a drop in quantity in the past five decades.

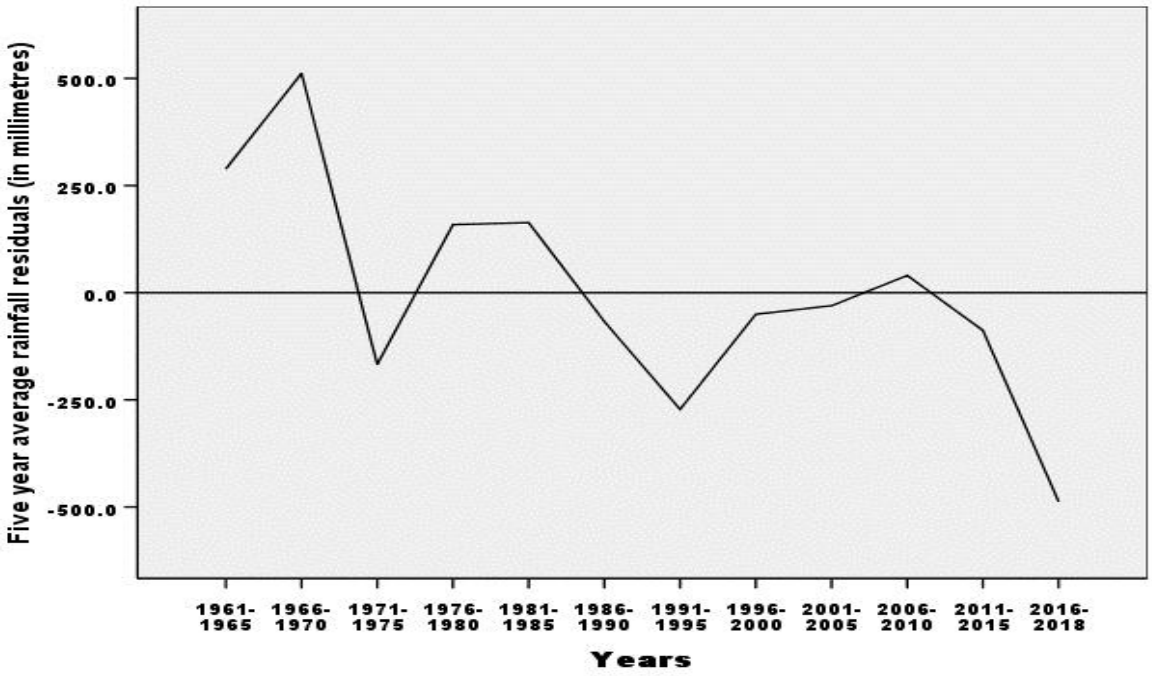

Figure 4.4: Annual rainfall residuals 1961-2018

4.1.1.1.3. Rainy days

There have equally been significant variations in the annual average rainy days between 1961-2018. The years with the highest annual average rainy days were 1961-1966, 1966-1970, 1976-1980, 1981-1985, 1991-1995, 1996-2000, and 2001-2005 characterized by annual average rainy days of 16, 17.7, 16.92, 16.5, 16.08, 17 and 16.5 respectively (Figure 4.5).

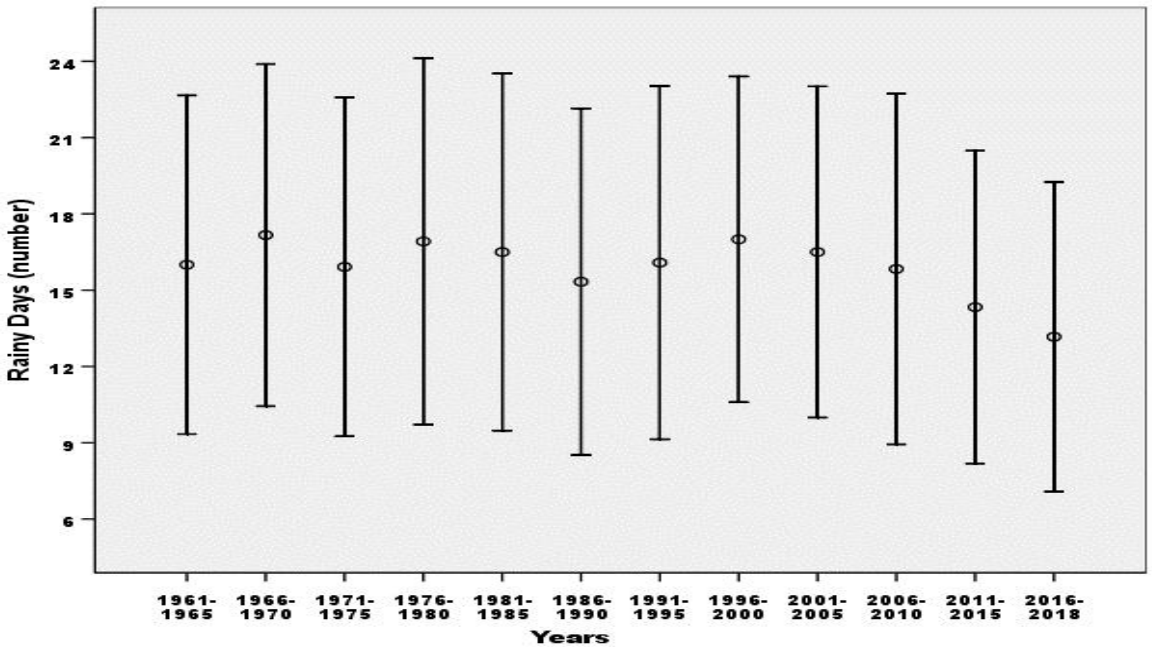

Figure 4.5: Annual average rainy days variation 1961-2018

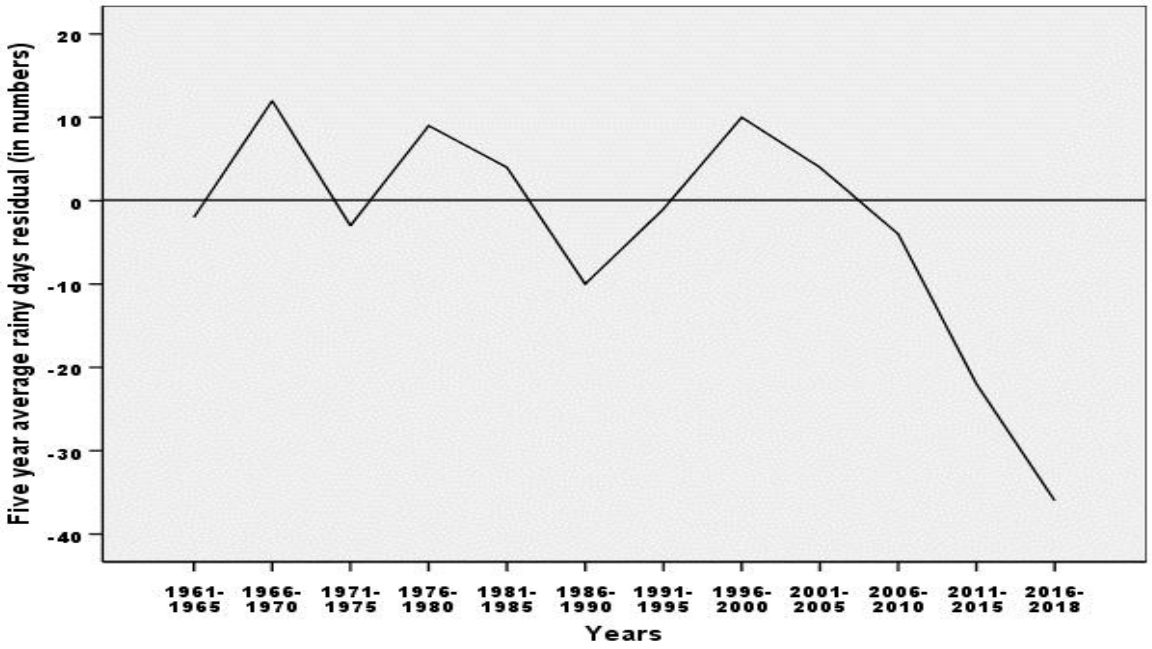

Figure 4.6: Annual rainy days residuals 1961-2018

Meanwhile the years with the least annual average rainy days were 1971-1975, 1986-1990, 2006-2010, 2011-2015 and 2016-2018 characterized by annual average rainy days of 15.92, 15.33, 15.83, 14.33 and 13.17 respectively. The highest annual average rainy days was 17.7 while the least annual average rainy days was 13.17 recorded in the years 1966-1970 and 2016-2018 respectively (Figure 4.5). Hence, the average number of rainy days per year have been varying enormously in the past five decades in the North-West Region of Cameroon.

As per the residuals of rainy days, it was found that most of the years experienced fewer rainy days. The years 1961-1965, 1971-1975, 1986-1990, 1991-1995, 2006-2010, 2011-2015 and 2016-2018 were most especially characterized by negative rainy days residuals of -2, -3, -10, -1, -4, -22 and -36 respectively. Whereas the years 1966-1970, 1976-1980, 1981-1985, 1996-2000 and 2001-2005 were characterized by positive rainy days residuals of 12, 9, 4, 10 and 4 respectively. Between 1961-2018, the highest positive rainy days residual was 12 days while highest negative rainy days residual was -36 days recorded in the years 1966-1970 and 2016-2018 respectively (Figure 4.6). Thus, the number of rainy days per year in the North-West Region of Cameroon has been varying significantly and becoming even fewer in the past five decades.

4.1.1.2. Causal and non-causal relationship between climate parameters

The scatter plot for rainfall and temperature showed the existence of a negative correlation between rainfall and temperature. This implies that as rainfall increase, temperature might decrease (Figure 4.7), or as temperature increases, rainfall might decrease (Figure 4.7).

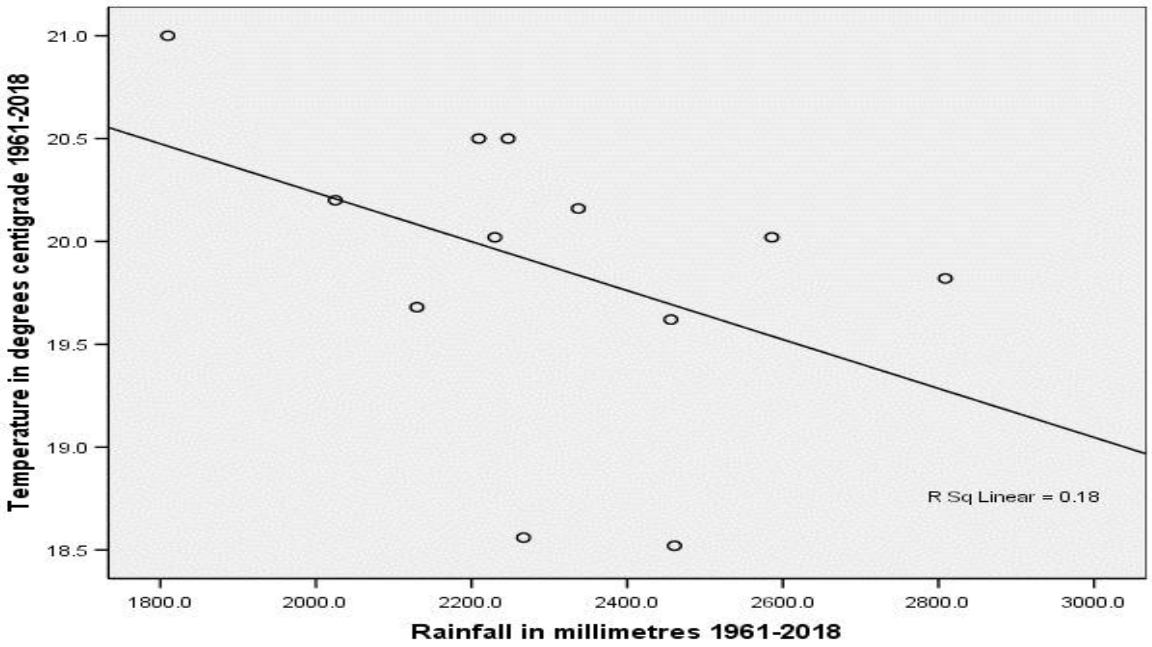

Figure 4.7: Relationship between rainfall and temperature 1961-2018

Meanwhile, the regression line indicated a negative causal relationship between rainfall and temperature (Figure 4.7). The R-square (R^2) of the regression line was 0.18, implying that 18% of variations in rainfall could be provoked by variations in temperature, and vice versa. Thus, there exists an interdependent relationship between temperature and rainfall faced with climate variability and change in the North-West Region of Cameroon.

The scatter plot for rainy days and temperature equally showed the existence of a negative correlation between rainy days and temperature. This demonstrates that as rainy days increases, temperature might decrease (Figure 4.8), and as temperature increases, rainy days might decrease **(**Figure 4.8**)**.

From the regression line, it was found that a negative causal relationship exists between rainy days and temperature (Figure 4.8). The R^2 of the regression line was 0.312, which goes to show that 31.2% of the variations in rainy days could be caused by variations in temperature, and vice versa. Hence, faced with climate variability and change, rainy days and temperature have an interdependent relationship in the North-West Region of Cameroon.

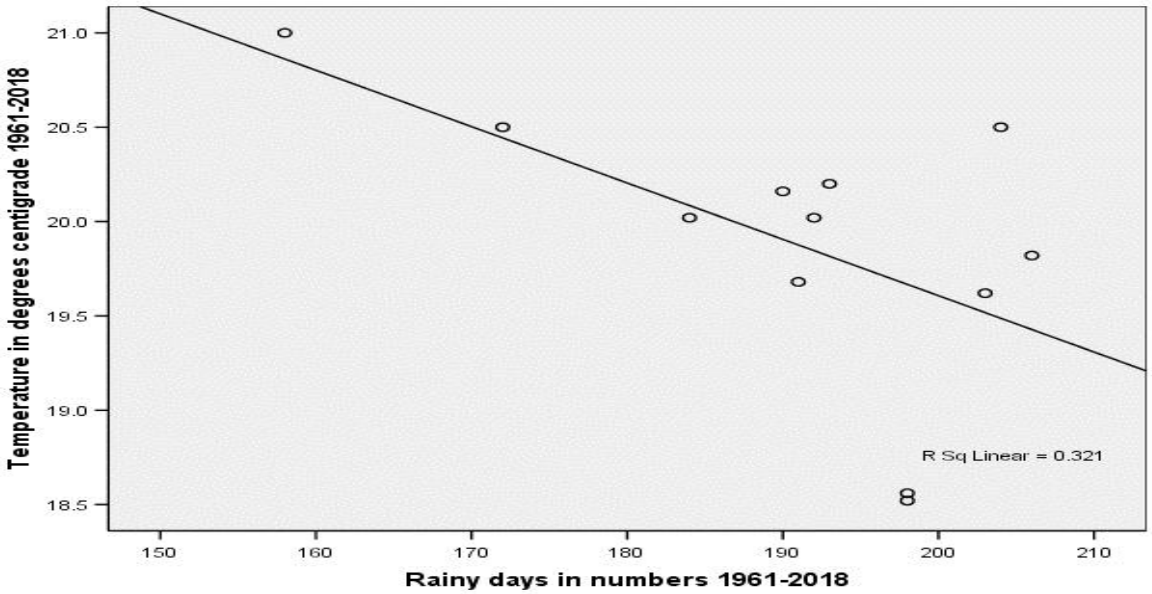

Figure 4.8: Relationship between rainy days and temperature

The scatter plot for rainy days and rainfall showed a positive correlation between rainy days and rainfall. This indicates that as rainy days increases, rainfall might increase (Figure 4.9), and as rainfall increases, rainy days might increase (Figure 4.9).

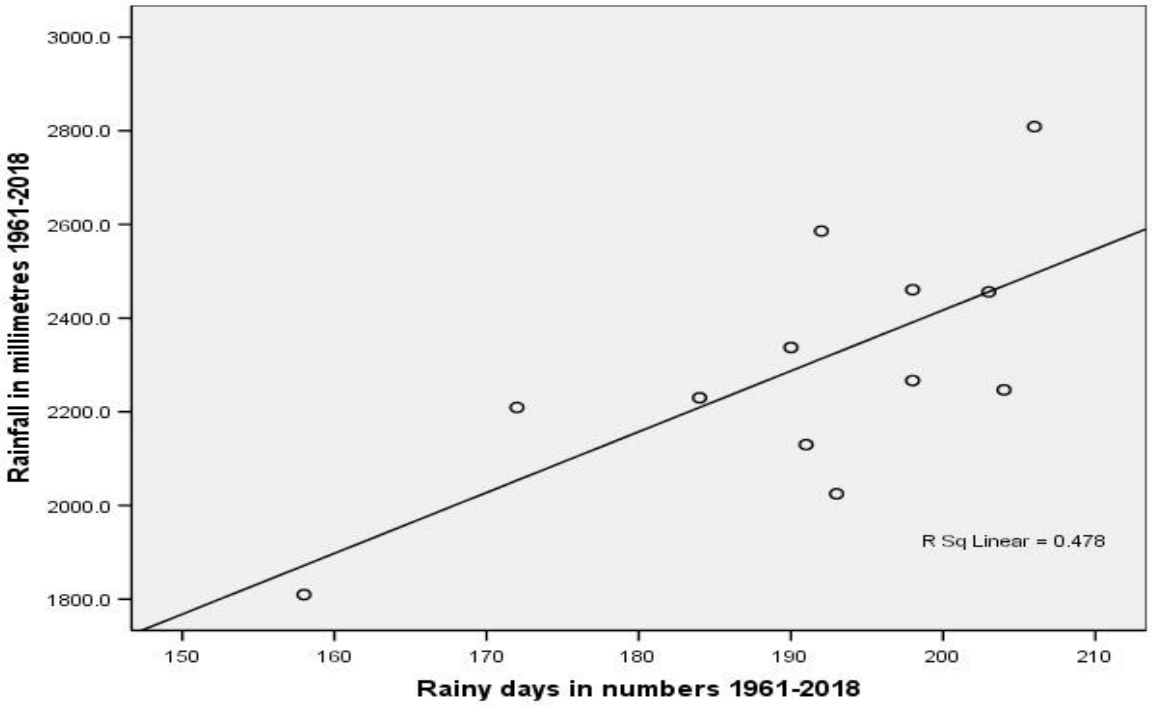

Figure 4.9: Relationship between rainy days and rainfall 1961-2018

Looking at the regression line, it was noticed that a positive causal relationship exists between rainy days and rainfall (Figure 4.9). The R^2 of the regression line being 0.478

implied that 47.8% of the variations in rainy days could be caused by variations in rainfall, and vice versa. Thus, rainfall and rainy days have a significant interdependent relationship, faced with climate variability and change in the North-West Region of Cameroon.

4.1.1.3. Smallholder farmers' perceptions of variability in climate parameters

Smallholder farmers perceived variations in climate parameters (temperature, rainfall, sunshine) differently across the study area.

With regards to temperature (Figure 4.10), most smallholder farmers perceived that, in the past three decades, temperature has been higher than usual (62%). Meanwhile 28.9% of the smallholder farmers perceived that temperature was high. Only 6%, 2.57% and 1.14% of the smallholder farmers perceived that temperature had stayed the same, low and very low respectively (Figure 4.10**).** This goes to show that, according to smallholder farmers' perceptions, temperature has very high and/or high in the past three decades.

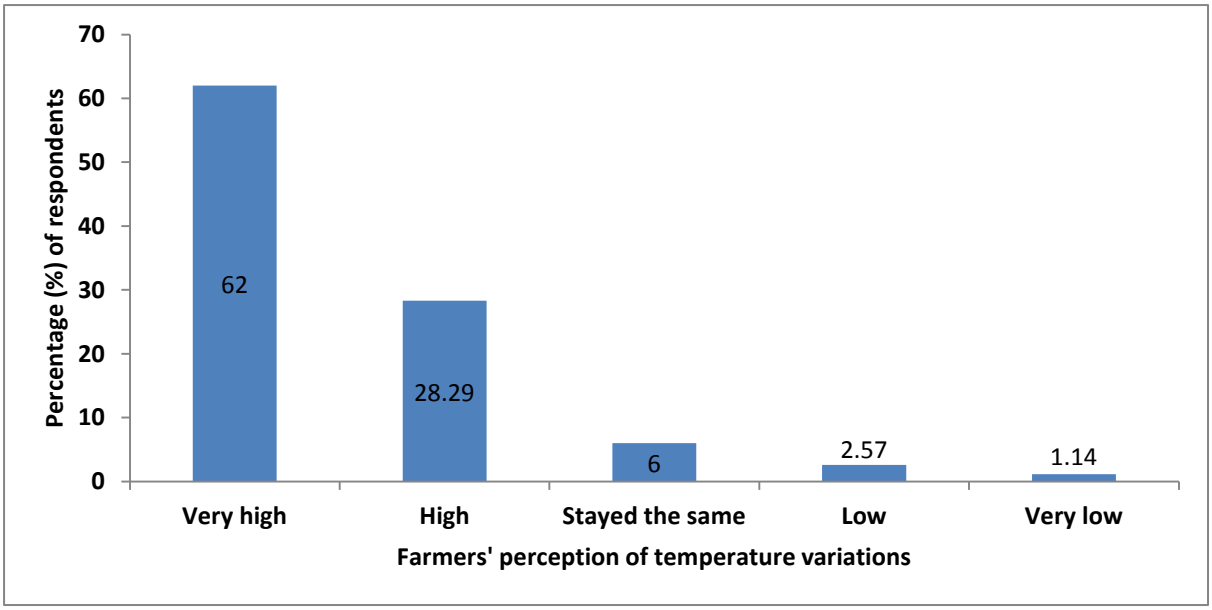

Figure 4.10: Smallholder farmers' perceptions of variations in temperature

Pertaining to sunshine (Figure 4.11), a majority of the smallholder farmers perceived that it has increased a lot in the past three decades (70.57%). Meanwhile 23.14% of the smallholder farmers perceived that it has increased. Just 3.71%, 2% and 0.58% of the smallholder farmers perceived that sunshine has stayed the same, decreased, and decreased a lot respectively (Figure 4.11). This demonstrates that a majority of smallholder farmers perceive an increase in the amount of sunshine in the past three decades.

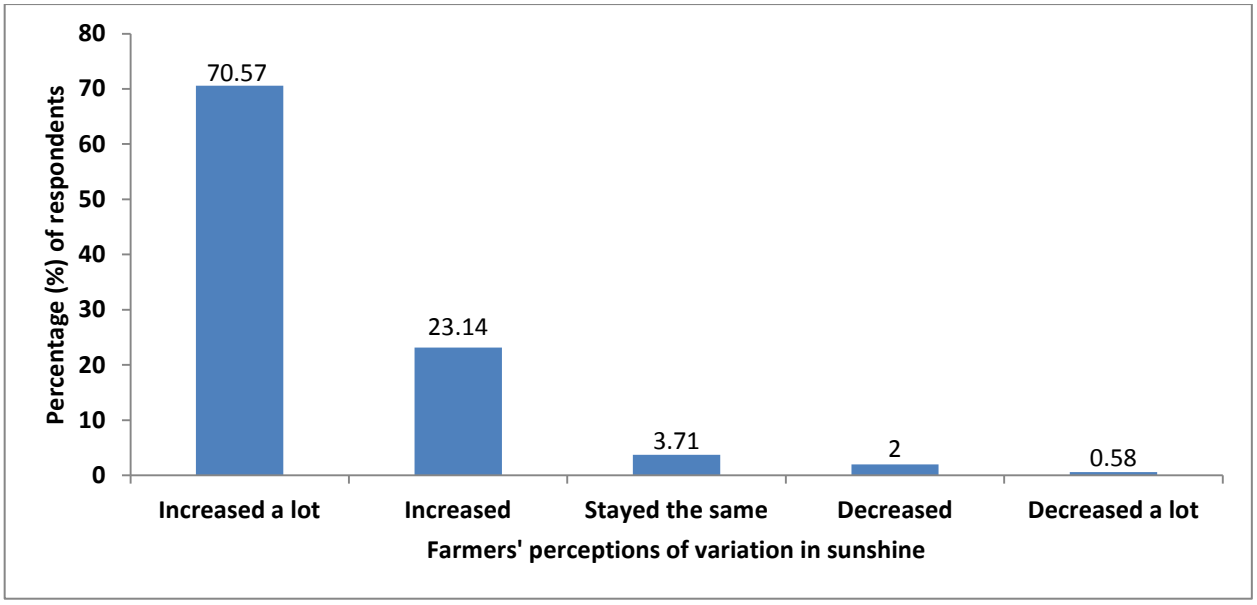

Figure 4.11: Smallholder farmers' perceptions of variations in sunshine

As concerns the quantity of rainfall (Figure 4.12), most of the smallholder farmers perceived that it has decreased in recent years (71.71%). Whereas 21.14% of the smallholder farmers perceived that it has decreased a lot. Merely 4.86%, 1.43% and 0.86% of the smallholder farmers perceived that quantity of rainfall has stayed the same, increased and increased a lot respectively (Figure 4.12). Hence, most smallholder farmers perceive a decrease in the quantity of rainfall in the past three decades.

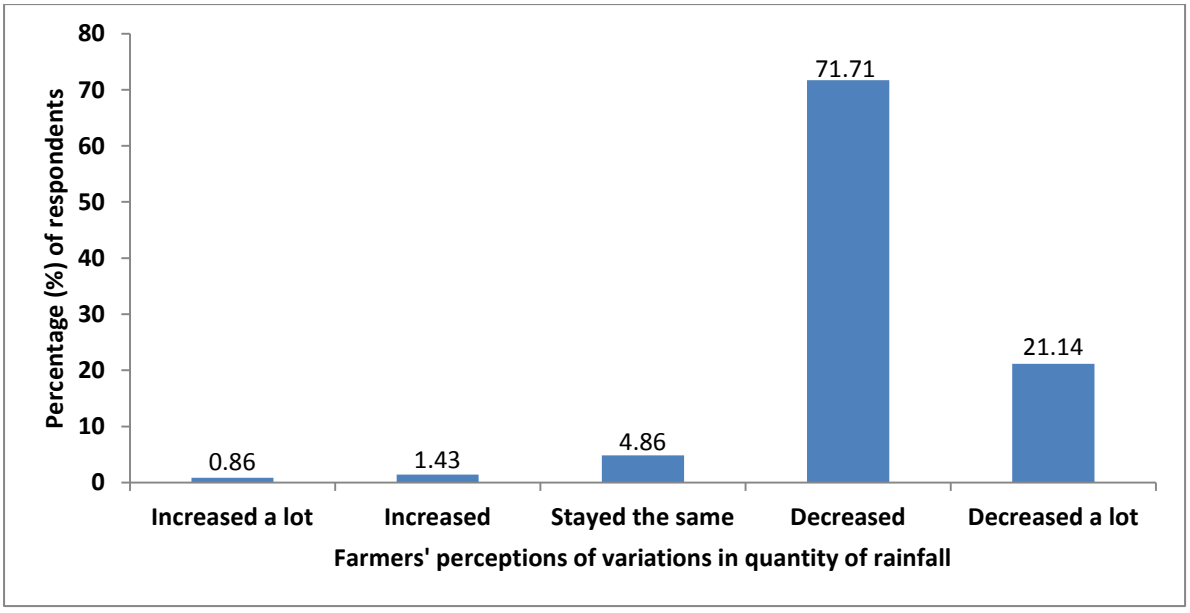

Figure 4.12: Smallholder farmers' perception of variations in quantity of rainfall

Pertaining to rainfall consistency (Figure 4.13), a majority of smallholder farmers perceived that rainfall has been much more variable in recent years (77.71%). While 14.86% of the

smallholder farmers perceived that rainfall has been more variable. Just 3.14%, 2.57%, and 1.71% of the smallholder farmers perceived that rainfall has stayed the same; become less variable and much less variable respectively (Figure 4.13). Thus, an overwhelming majority of smallholder farmers perceive that rainfall has become very inconsistent (much more variable or more variable) in the past three decades.

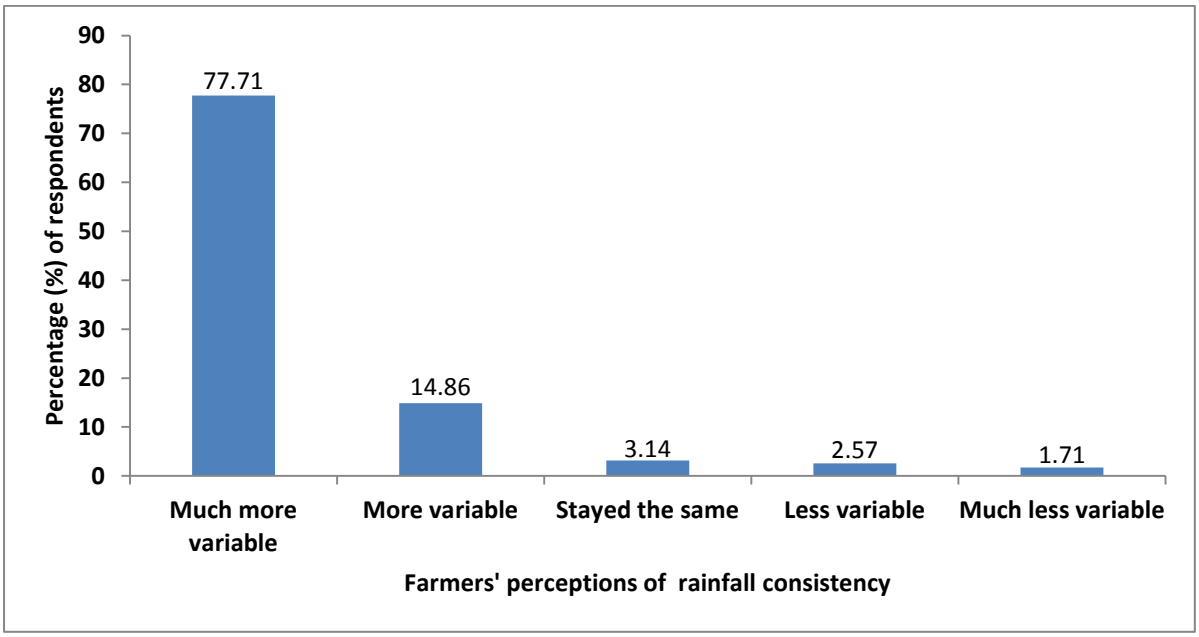

Figure 4.13: Smallholder farmers' perceptions of consistency in rainfall

Hence, smallholder farmers' perceived variations in climate parameters matches almost perfectly with variations found through the analysis of climate data for the study area, indicating a congruence between smallholder farmers' perceptions and analyzed climate data for the North-West Region of Cameroon.

4.1.1.4. Farmer perceived drivers of vulnerability to climate variability and change

As concerns smallholder farmers' vulnerability to climate variability and change (CVC) (Figure 4.14), most smallholder farmers were almost unanimous that recurrent extreme weather events (99.25%) and poverty (95.9%) were the major drivers of vulnerability to climate variability and change.

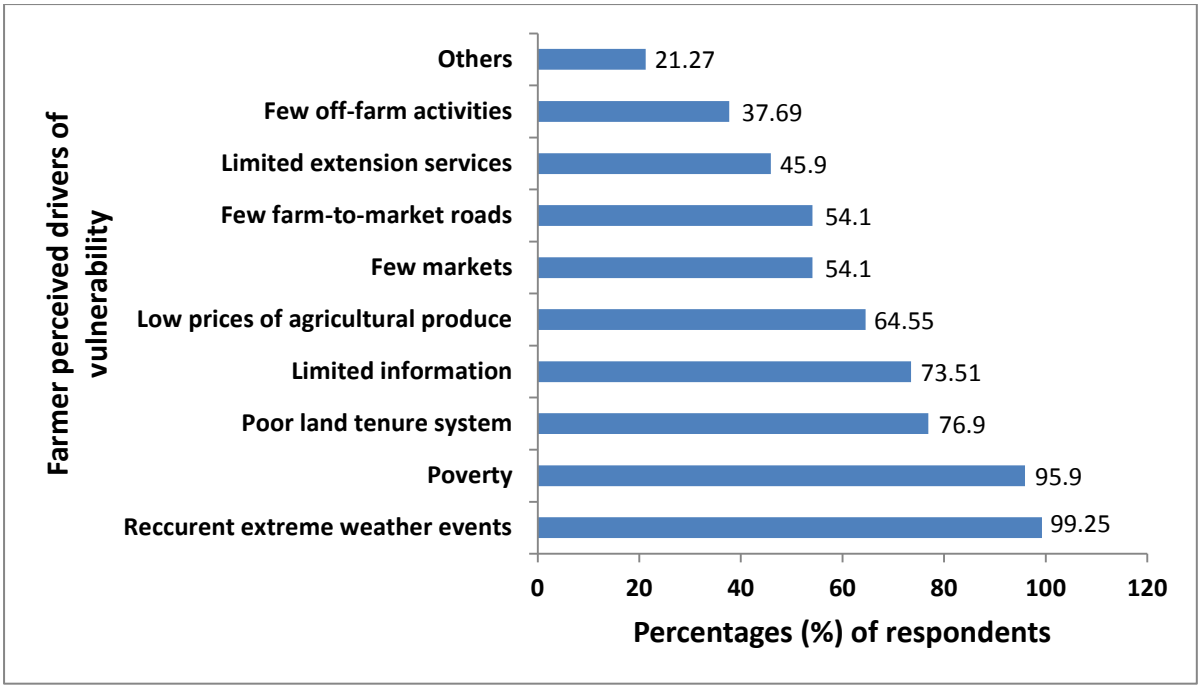

Figure 4.14: Smallholder farmer perceived drivers of vulnerability to climate variability and change

Poor land tenure systems (76.9%), limited information (73.51%) and low prices of agricultural produce (64.55%) were equally identified by smallholder farmers as some of the main sources of their vulnerability to climate variability and change. Not leaving out few organized markets (54.1%), few farm-to-market roads (54.1%), limited agricultural extension services (45.9%), few off-farm jobs (37.69%) and others (21.27%) like soil infertility and hilly terrain. Over all, it is seen that the main drivers of smallholder farmers' vulnerability in the study area are recurrent extreme weather events, poverty, poor land tenure systems and limited information (Figure 4.14). Therefore, the drivers of smallholder farmers' vulnerability to climate variability and change are varied; and smallholder farmers often perceive a combination of drivers triggering vulnerability to climate variability and change.

4.1.1.5. Degree of vulnerability to climate variability and change as perceived by smallholder farmers

Pertaining to the degree of vulnerability of smallholder farmers faced with climate variability and change (Figure 4.15), most smallholder farmers perceived that they were highly vulnerable (57.43%). Meanwhile 23.43% of the smallholder farmers perceived that they were not vulnerable to climate variability and change. 15.14% of the smallholder farmers

perceived that they were vulnerable to climate variability and change. Merely 3.14% and 0.86% of the smallholder farmers perceived that they were less vulnerable and much less vulnerable respectively to climate variability and change. Based on these perceptions, it is clear that most smallholder farmers feel that they are vulnerable to climate variability and change (Figure 4.15). Thus, most smallholder farmers in the North-West Region of Cameroon are highly vulnerable to climate variability and change.

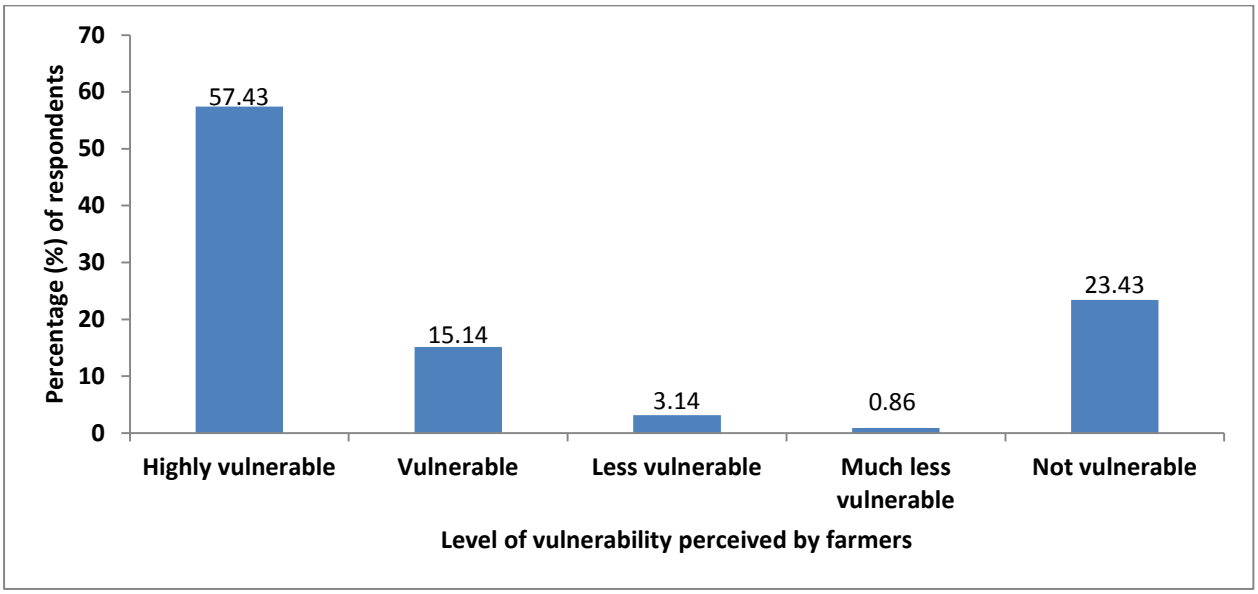

Figure 4.15: Smallholder farmers' perceived degree of vulnerability to climate variability and change

4.1.1.6. Factors affecting smallholder farmers' vulnerability to climate variability and change

4.1.1.6.1. Relationship between explanatory variables and smallholder farmers' vulnerability to climate variability and change

An analysis of the relationship between smallholder farmers' vulnerability to climate variability and eleven explanatory variables revealed that there was an inverse relationship between vulnerability and all these explanatory variables (Table 4.1).

Explanatory variables like number of farms, household size, age of household head, household income, level of education of household head, access to information, access to credit facilities and access to land all had a strong inverse relationship with smallholder farmers' vulnerability. This implies that an increase in any of these explanatory variables

probably leads to a very drastic reduction in smallholder farmers' vulnerability to climate variability and change.

Table 4.1: Spearman rank correlation coefficient showing relationship between vulnerability and explanatory variables

Explanatory variable	Spearman correlation coefficient	Degree and type of relationship
Number of farms	- 0.786***	Strong negative or inverse
Household size	- 0.630***	Strong negative or inverse
Age of household head	- 0.627***	Strong negative or inverse
Household income	- 0.702***	Strong negative or inverse
Level of education of HHH	- 0.816***	Strong negative or inverse
Gender of household head	- 0.472	Weak negative or inverse
Practice of agroforestry	- 0.282	Weak negative or inverse
Access to information	- 0.535***	Strong negative or inverse
Access to credit facilities	- 0.794***	Strong negative or inverse
Access to land	- 0.546***	Strong negative or inverse
Access to extension services	- 0.479	Weak negative or inverse

******* Significant at 1% probability level

Although explanatory variables like gender of household head, practice of agroforestry and access to agricultural extension services had weak inverse relationships with smallholder farmers' vulnerability, it still goes to show that an increase in any of these explanatory variables probably leads to a reduction (although less drastic) in smallholder farmers' vulnerability to climate variability and change. Hence, there exists a correlation (non-causal relationship) between smallholder farmers' vulnerability to climate variability and change, and various explanatory/independent variables, which indicates that smallholder farmers' vulnerability faced with climate variability and change could be directly or indirectly linked to these independent/explanatory variables.

4.1.1.6.2. Non-causal relationship between smallholder farmers' vulnerability to climate variability and change, and continuous and discontinuous explanatory variables

4.1.1.6.2.1. Non-causal relationship between smallholder farmers' vulnerability and continuous explanatory variables

Results from the t-test statistic revealed that there was a significant non-causal relationship between smallholder farmers' vulnerability and four continuous explanatory variables ($p<0.001$) (Table 4.2).

Table 4.2: Independent sample t-test statistic showing non-causal relationship between vulnerability and continuous explanatory variables

		Levene's test for the equality of variance		t-test for equality of means			
Variable	**Assumption**	**F**	**p-value**	**t**	**df**	**p-value**	**Mean diff.**
Number of farms	Equal variance assumed	53.455	0.000***				
	Equal variance not assumed			24.786	92.987	0.000***	5.507
Household size	Equal variance assumed	34.832	0.000***				
	Equal variance not assumed			13.972	97.832	0.000***	3.195
Age of household head	Equal variance assumed	12.259	0.001***				
	Equal variance not assumed			15.665	106.536	0.000***	9.917
Annual income of household	Equal variance assumed	50.754	0.000***				
	Equal variance not assumed			17.847	94.135	0.000***	347902.26

***** Significant at 0.1% probability level**

Continuous explanatory variables like number of farms ($t = 24.786$, $p<0.001$), household size ($t = 13.972$, $p<0.001$), age of household head ($t = 15.665$, $p<0.001$), and household income ($t = 17.847$, $p<0.001$), all had a significant non-causal relationship with smallholder farmers' vulnerability to climate variability and change. This is vivid indication that number of farms owned, household size, age of household head, and household income play a plausibly significant role in influencing smallholder farmers' vulnerability to climate variability and change.

4.1.1.6.2.2. Non-causal relationship between smallholder farmers' vulnerability and discontinuous explanatory variables

Chi-square test results showed that there was a statistically significant non-causal relationship between smallholder farmers' vulnerability and seven (07) discontinuous explanatory variables ($p<0.001$) (Table 4.3).

Discontinuous explanatory variables like level of education of household head ($X^2 = 317.60$, $p<0.001$), gender of household head ($X^2 = 77.90$, $p<0.001$), practice of agroforestry ($X^2 = 27.74$, $p<0.001$), access to information ($X^2 = 100.18$, $p<0.001$), access to credit ($X^2 = 220.71$, $p<0.001$), access to land ($X^2 = 104.36$, $p<0.001$) and access to agricultural extension services

(X^2 = 80.16, p<0.001), all had a statistically significant non-causal relationship with smallholder farmers' vulnerability to climate variability and change.

Table 4.3: Chi-square test statistic showing non-causal relationship between vulnerability and discontinuous explanatory variables

Discontinuous Variable	Description	Frequency (n)		Percentage (%)		Chi-square	L.R.	p-level
		V.	N.V.	V.	N.V.			
Educational Level of household head	No formal edu.	31	2	8.86	0.57	317.60	325.27	0.000***
	Primary	237	4	67.71	11.43			
	Secondary	0	10	0	2.86			
	High school	0	35	0	10			
	Tertiary	0	31	0	8.86			
Gender of household head	Male	113	80	32.29	22.86	77.90	97.77	0.000***
	Female	155	2	44.29	0.57			
Practice Agroforestry	Yes	196	82	56	23.43	27.74	43.85	0.000***
	No	72	0	20.57	0			
Access to information	Yes	10	39	2.86	11.14	100.18	84.60	0.000***
	No	258	43	73.71	12.29			
Access to credit	Yes	6	63	1.71	18	220.71	201.26	0.000***
	No	262	19	74.86	5.43			
Access to land	Yes	16	45	4.57	12.86	104.36	89.72	0.000***
	No	252	37	72	10.57			
Access to extension	Yes	24	44	6.86	12.57	80.16	69.82	0.000***
	No	244	38	69.71	10.86			

******* Significant at 0.1% probability level; V. = vulnerable; N.V. = Not vulnerable; L.R. = Likelihood Ratio; info. = information; edu. = education

The chi-square test statistic clearly showed that level of education of household head, gender of household head, practice of agroforestry, access to information, access to credit, access to land and access to agricultural extension services plausibly affects smallholder farmers' vulnerability. Hence, the discontinuous explanatory variables educational level of household head, gender of household head, practice of agroforestry, access to information, access to credit, access to land, and access to agricultural extension services play a plausibly significant role in affecting smallholder farmers' vulnerability to climate variability and change.

4.1.1.6.3. Ranking smallholder farmers' vulnerability to climate variability and change according to location

The Kruskall-Wallis test was run to rank vulnerability to climate variability and change, and to determine if there was a significant variation in smallholder farmers' vulnerability to climate variability and change across ten villages (Mankon, Nkwen, Bambui, Bambili, Kedjom Keku, Mendakwe, Mbei-Santa, Akum, Njong-Santa, and Awing) (Table 4.4).

Table 4.4: Kruskall-Wallis test statistic showing variation in vulnerability according to village

Village	Frequency (n)		Percentage (%)		Mean rank	Chi-square	p-level
	Vulnerable	Not vulnerable	Vulnerable	Not vulnerable			
Mankon	33	7	82.5	17.5	185.88		
Nkwen	32	8	80	20	181.50		
Bambui	33	7	82.5	17.5	185.88		
Bambili	33	7	82.5	17.5	185.88		
Kedjom Keku	21	9	70	30	164.00	6.097	0.730
Mendakwe	23	7	76.7	23.3	175.67		(ns)
Mbei-Santa	22	8	73.3	26.7	169.83		
Akum	28	12	70	30	164.00		
Njong-Santa	23	7	76.7	23.3	175.67		
Awing	20	10	66.7	33.33	158.17		

ns = not significant

The Kruskall-Wallis test (H-test) confirmed that there was no significant variation in vulnerability amongst smallholder farmers across the different villages (X^2 = 6.097, p> 0.1). This goes to show that smallholder farmers' vulnerability does not vary significantly with location. Although the mean rank indicates that smallholder farmers in villages like Mankon (mean rank = 185.88), Bambui (mean rank = 185.88) and Bambili (mean rank = 185.88) are relatively vulnerable than their counterparts in villages like Awing (mean rank = 158.17), Mbei-Santa (mean rank = 169.83) and Kedjom Keku (mean rank = 164) (Table 4.4).

4.1.1.6.4. Causal relationship between smallholder farmers' vulnerability to climate variability and change, and explanatory variables

The Binary logistic regression model revealed that there was a statistically significant inverse causal relationship between smallholder farmers' vulnerability to climate variability and change and five (05) explanatory variables (Table 4.5).

From the predictions of this model, household size (β = -1.815, p<0.01), age of household head (β = -0.695, p<0.05), household income (β = -6.321, p<0.01), access to information (β = -5.387, p<0.05), and access to land (β = -4.239, p<0.05) all contributed in drastically reducing smallholder farmers' vulnerability to climate variability and change. This goes to show that as household size increases; as household income increases; as age of household head increases; as access to information increases; and as access to land increases; there is a decrease in smallholder farmers' vulnerability to climate variability and change. Thus, the findings of the study demonstrate that some continuous and discontinuous explanatory

variables like household size, age of household head, household income, access to information and access to land play a significant role in reducing smallholder famers' vulnerability to climate variability and change.

Table 4.5: Binary logistic regression predicting smallholder farmers' vulnerability to climate variability and change from five explanatory variables

Explanatory variables	**Coefficients (β)**	**p-level**	**Wald**	**df**	**Odds ratio (Exp β)**	**95% C.I. for Exp β**	
						Lower	**Upper**
Household size	-1.815***	0.005	7.985	1	0.163	0.046	0.573
Age of household head	-0.695**	0.021	5.307	1	0.499	0.276	0.901
Household income	-6.321***	0.002	3.532	1	0.001	0.000	0.350
Access to information	-5.387**	0.027	4.906	1	0.005	0.000	0.538
Access to land	-4.239**	0.040	4.231	1	0.014	0.000	0.819
Constant	48.169***	0.003	8.898	1	83055688959 2572400000		
-2 Log likelihood	18.033						
Likelihood ratio X^2	363.05***	0.000					
Nagelkerke R^2	0.973						
Number of cases correctly classified	99.7%						

****, ***** Significant at 5% and 1% probability levels respectively

It must be said that the parameter estimates of this model are valid looking at the Likelihood Ratio X^2, the Nagelkerke R^2 and the number of cases correctly classified. Likelihood Ratio X^2 (5, n = 350 =363.05, p<0.001), indicated that the model is statistically significant and has a strong explanatory power. Nagelkerke R^2 (0.973) demonstrated that the model explained up to 97.3% of the variations in smallholder farmers' vulnerability faced with climate variability and change. Moreover, the model correctly classified up to 99.7% of smallholder farmers' vulnerability to climate variability and change. Looking at all these, it can be said that the predictions of this model are very much valid as far as predicting the factors influencing smallholder farmers' vulnerability to climate variability and change in the North-West Region of Cameroon are concerned.

4.1.2. Characterized agroforestry practices of smallholder farmers in the face of climate variability and change

4.1.2.1. Identified and categorized agroforestry practices of smallholder farmers

4.1.2.1.1. Identified agroforestry practices of smallholder farmers

The agroforestry practices of smallholder farmers in the face of climate variability and change were generally varied, and most smallholder farmers were into several agroforestry practices at a time (Figure 4.16).

Among the agroforestry practices taken up by smallholder farmers, home garden with livestock was the most widespread (52.88%). This was closely followed by trees on croplands (47.84%) and the home garden (43.52%). Live fences/hedges (37.05%), trees on grazing lands (34.53%) and coffee-based agroforestry (29.5%) equally featured prominently among the agroforestry practices taken up by smallholder farmers. Meanwhile, very few smallholder farmers were into Taungya (18.34%), improved fallows (12.59%) and others (4.68%) like fodder banks, windbreaks and trees on grazing lands with crops (Figure 4.16).

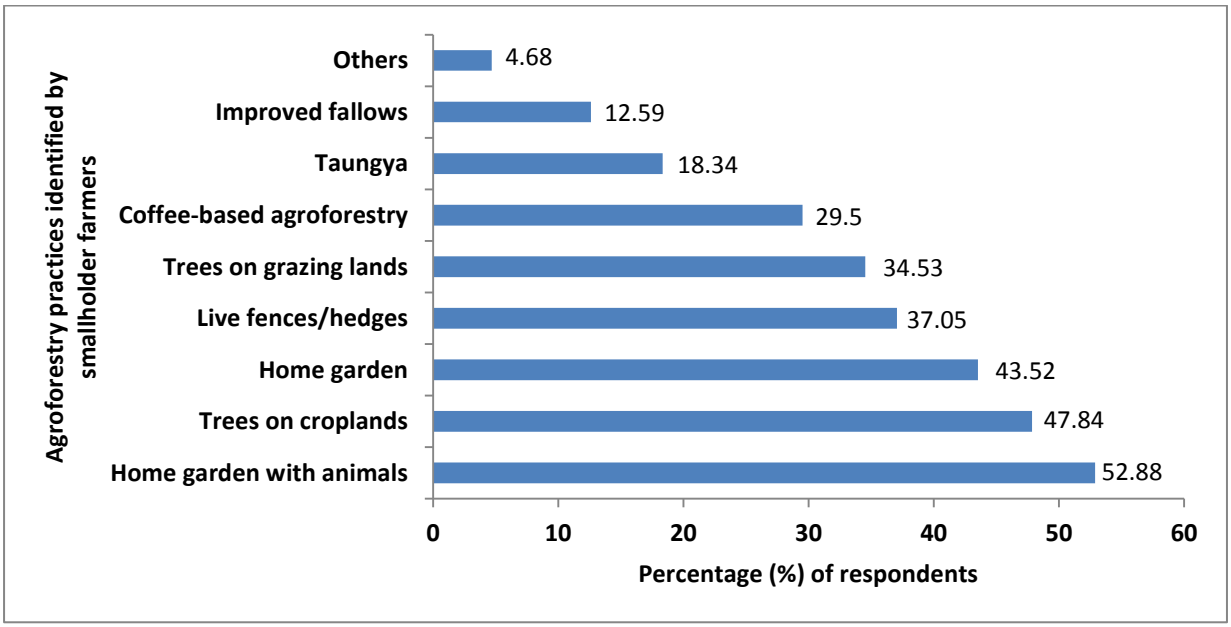

Figure 4.16: Agroforestry practices of smallholder farmers

Therefore, smallholder farmers take to a plethora of agroforestry practices faced with the impacts of climate variability and change.

4.1.2.1.2. Categorized agroforestry practices of smallholder farmers

The agroforestry practices of smallholder farmers were categorized under three main systems: agrosilvicultural, silvopastoral, and agrosilvopastoral (Table 4.6).

Table 4.6: Categorized agroforestry practices of smallholder farmers

Agroforestry system	Agroforestry practice	Components
Agrosilvicultural	Home garden	Trees and different types of crops
	Trees on croplands	Trees and food crops
	Live fences/hedges	Trees and food crops
	Taungya	Trees and food crops
	Coffee-based agroforestry	Trees and cash crop
	Improved fallows	Shrubs and crops
	Windbreaks	Trees and crops
Silvopastoral	Trees on grazing lands	Trees and livestock/fodder crops
	Fodder banks	Trees and fodder crops
Agrosilvopastoral	Home gardens with livestock	Trees, crops and livestock
	Trees on grazing lands with crops	

Under the agrosilvicultural system, there were six (06) main agroforestry practices of smallholder farmers: home garden, trees on croplands, live fences/hedges, Taungya, coffee-based agroforestry, improved fallows and windbreaks (Table 4.6). As for the silvopastoral system, two main agroforestry practices were identified: trees on grazing lands and fodder banks (Table 4.6). Pertaining to the agrosilvopastoral system, two main practices were identified: home garden with livestock and trees on grazing lands with crops (Table 4.6). Thus, basically three main agroforestry systems and several agroforestry practices are taken up by smallholder farmers faced with climate variability and change.

4.1.2.2. Ecosystem services of agroforestry identified by smallholder farmers practicing agroforestry

Smallholder farmers identified a plethora of ecosystem services resulting from their diverse agroforestry practices (Figure 4.17).

Among the different ecosystem services identified by smallholder farmers, food (100%) and fuelwood (100%) were unanimously identified by all the smallholder farmers practicing agroforestry. This was closely followed by natural (traditional) medicines and building materials identified by 76.62% and 71.22% of the smallholder farmer agroforestry practitioners respectively.

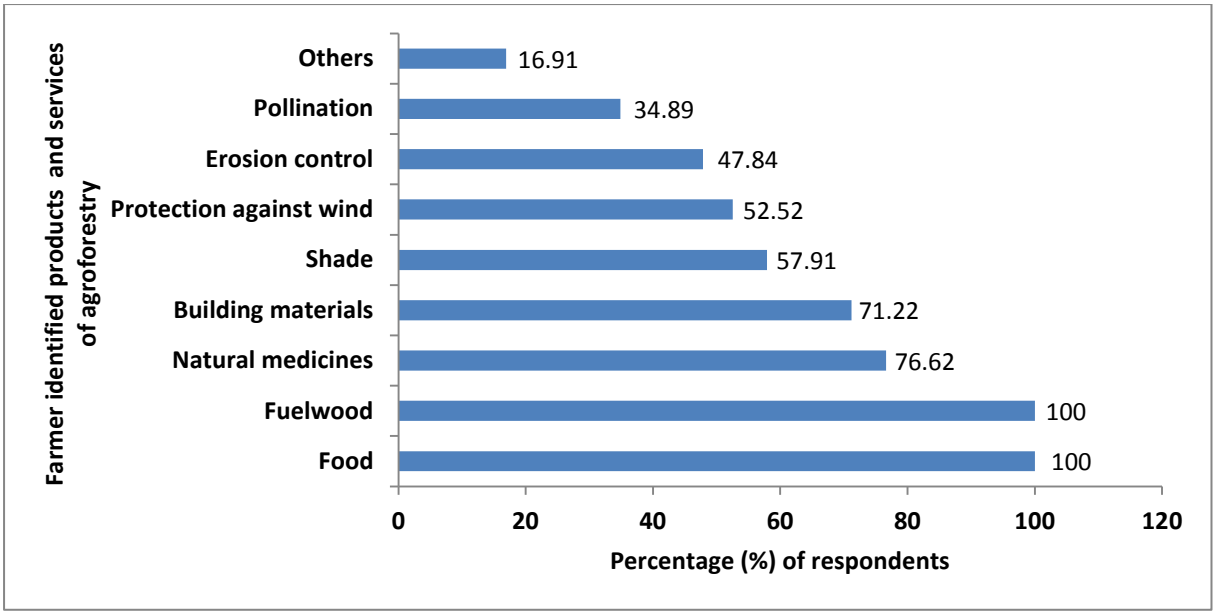

Figure 4.17: Ecosystem services of agroforestry identified by smallholder farmers

Meanwhile ecosystem services such as provision of shade, protection against the wind, and erosion control were identified by 57.91%, 52.52% and 47.84% of the smallholder farmer agroforestry practitioners respectively. Only 34.89% and 16.91% of the smallholder farmer agroforestry practitioners identified pollination and others (finance and micro-climate buffering) respectively. This demonstrates that smallholder farmers practicing agroforestry derive several benefits (ecosystem services).

4.1.2.3. Main classes of agroforestry tree/shrub species integrated in smallholder farmers' plots

Following field surveys (inventories on farmers' agroforestry plots), it was found that the most common categories of agroforestry tree/shrub species integrated in smallholder farmers' agroforestry plots were fruit trees (100%), fuelwood trees/shrubs (100%), trees/shrubs for building materials (98%), trees for windbreaks (83%), and trees for soil improvement (73%). Fodder trees/shrubs (69%), trees for medicines (51%), trees for food (25%) and others (7%) were equally integrated on smallholder farmers' agroforestry plots (Table 4.7).

Table 4.7: Classes of agroforestry tree/shrub species found on smallholder farmers' agroforestry plots

Class of agroforestry tree/shrub	Frequency (n)	Percentage (%)	Number of agroforestry plots surveyed (N)
Fruit trees	200	100	
Fuelwood trees/shrubs	200	100	
Trees/shrubs for building materials	196	98	
Fodder trees/shrubs	138	69	
Trees for windbreaks	166	83	200
Trees for soil improvement	146	73	
Trees for medicines	102	51	
Trees for food	50	25	
Others (e.g. flowering trees for apiculture)	14	7	

Thus, a diverse category of agroforestry tree/shrub species were integrated by smallholder farmers on their farm plots faced with the impacts of climate variability and change.

4.1.2.4. Major food and cash crop species integrated in smallholder farmers' agroforestry farm plots

Field surveys indicated that the most common herbaceous species integrated in smallholder farmers' agroforestry plots were *Zea mays* (98%), *Manihot esculenta* (92%), *Colocasia spp* (85%), *Phaseolus vulgaris* (75%), *Vigna unguiculata* (80%), *Ipomoea batatas* (64%) and *Musa spp* (56%) (Table 4.8).

Table 4.8: Food and cash crop species integrated on smallholder farmers' agroforestry plots

Food and cash crop species	Frequency (n)	Percentage (%)	Number of agroforestry plots surveyed (N)
Zea mays (maize)	196	98	
Coffea (coffee)	35	17.5	
Elaies guineensis (oil palms)	98	49	
Manihot esculenta (cassava)	184	92	
Colocasia spp (cocoyams)	170	85	
Phaseolus vulgaris (beans)	150	75	
Vigna unguiculata (cowpea)	160	80	200
Ipomoea batatas (sweet potato)	128	64	
Musa spp (plantain and banana)	112	56	
Solanum tuberosum (potato)	19	9.5	
Dioscorea spp (yams)	96	48	
Arachis hypogaea (groundnuts)	60	30	
Others (vegetables and market gardening crops)	30	15	

Meanwhile the least integrated food and cash crops on smallholder farmers' agroforestry plots were *Coffea arabica* (17.5%), *Elaies guineensis* (49%), *Solanum tuberosum* (9.5%), *Dioscorea spp* (48%), *Arachis hypogaea* (30%) and others especially vegetables and market gardening crops (15%) (Table 4.8). Hence, smallholder farmers integrate a variety of crops in their agroforestry plots ranging from food crops, cash crops to even vegetables and market gardening crops in the face of climate variability and change.

4.1.2.5. Common livestock species raised by smallholder farmers practicing agroforestry

Out of the many livestock species reared by smallholder farmers practicing agroforestry, it was found that a majority of the smallholder farmers raised *Gallus gallus domesticus* or the indigenous fowl (72.3%), *Sus domesticus* or the domestic pig (65.11%), *Capra aegagrus hircus* or the domestic goat (47.48%) and *Ovis aries* or the sheep (38.49%) (Figure 4.18).

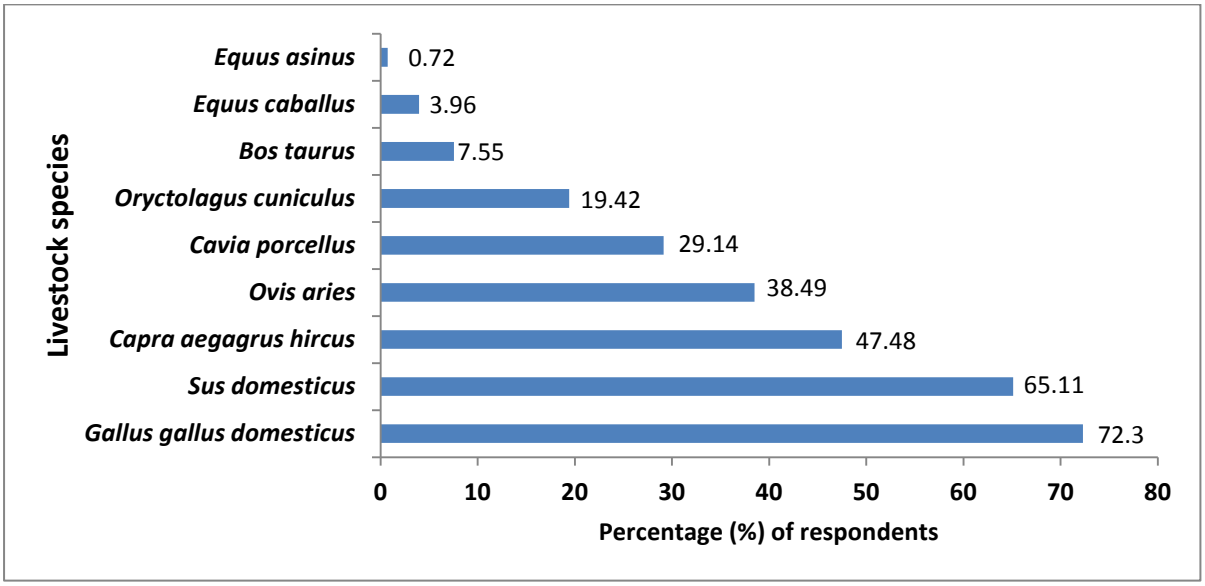

Figure 4.18: Livestock species reared by smallholder farmers practicing agroforestry

Meanwhile fewer smallholder farmers practicing agroforestry were into the rearing of *Cavia porcellus* or the guinea pig (29.14%), *Oryctolagus cuniculus* or the domestic rabbit (19.42%), *Bos Taurus* or cattle (7.55%), *Equus caballus* or domestic horse (3.96%) and *Equus asinus* or donkey (0.72%) (Figure 4.18).

4.1.2.6. Common tree/shrub species integrated within smallholder farmers' agroforestry plots

From field surveys of two hundred (200) smallholder farmers' agroforestry plots, it was found that the most common tree/shrub species integrated by smallholder farmers on their agroforestry farm plots were *Persea americana* (93%), *Psidium guajava* (91.5%), *Vernonia amygdalina* (90.5%), *Casuarina equisetifolia* (50.5%), *Albizzia ferruginea* (49.5%), *Calliandra calothyrsus* (53%), *Leucaena leucocephala* (42%), *Eucalyptus spp* (53.5%), *Carica papaya* (45.5%), *Rauvolfia vomitoria* (46%), *Prunus africana* (41.5%), *Dacryodes edulis* (81.5%), *Canarium schweinfurtii* (41%), *Mangifera indica* (77%), *Elaies guineensis* (49%) and *Cola anomala* (52%) (Table 4.9).

Table 4.9: Main tree/shrub species integrated by smallholder farmers on their agroforestry plots

Scientific name	Freq. (n)	(%)	Scientific name	Freq. (n)	(%)
Persea americana	186	93	*Adansonia digitata*	9	4.5
Cola anomala	104	52	*Ceiba pentandra*	68	34
Elaeis guineensis	98	49	*Albizia ferruginea*	99	49.5
Mangifera indica	154	77	*Albizia zygia*	43	21.5
Canarium schweinfurtii	82	41	*Albizia adianthifolia*	21	10.5
Dacryodes edulis	163	81.5	*Gliricia sepium*	72	36
Psidium guajava	183	91.5	*Leucaena leucocephala*	84	42
Vernonia amygdalina	181	90.5	*Calliandra calothyrsus*	106	53
Citrus grandis	16	8	*Podocarpus mannii*	75	37.5
Citrus limon	10	5	*Ficus thonningii*	37	18.5
Citrus reticulate	11	5.5	*Antiaris africana*	4	2
Citrus sinensis	39	19.5	*Militia excels*	24	12
Prunus Africana	83	41.5	*Ficus exasperate*	48	24
Rauvolfia vomitoria	92	46	*Vitex ciliate*	66	33
Voacanga Africana	71	35.5	*Khaya senegalensis*	22	11
Myrianthus arboreus	2	1	*Eucalyptus spp*	107	53.5
Uapaca guineensis	19	9.5	*Carica papaya*	91	45.5
Pycnanthus angolensis	25	12.5	*Ficus chlamydocarpa*	33	16.5
Spondianthus preussii	13	6.5	*Milletia courauri*	12	6
Terminalia glaucescens	47	23.5	*Ficus elastic*	15	7.5
Gmelina arborea	74	37	*Citrus aurantifolia*	6	3
Casuarina equisetifolia	101	50.5	*Sesbania sesban*	41	20.5
Sesbania macrantha	52	26	*Tephrosia vogelii*	17	8.5
Pinus sylvestris	26	13	*Raphia spp*	75	37.5

Meanwhile the least common tree/shrub species (with less than 10% representation on smallholder farmers' agroforestry farm plots) were *Citrus grandis* (8%), *Citrus limon* (5%),

Citrus reticulate (5.5%), *Myrianthus arboreus* (1%), *Uapaca guineensis* (9.5%), *Spondianthus preussii* (6.5%), *Adansonia digitata* (4.5%), *Antiaris africana* (2%), *Milletia courauri* (6%), *Ficus elastic* (7.5%), *Citrus aurantifolia* (3%) and *Tephrosia vogelii* (8.5%) (Table 4.9). Thus a total of 47 different species were identified on the 200 smallholder farmers' agroforestry plots surveyed. This goes to show that smallholder farmers integrate a wide variety of tree/shrubs species on their agroforestry plots faced with the impacts of climate variability and change.

4.1.3. Agroforestry practices and smallholder farmers' vulnerability to climate variability and change

4.1.3.1. Factors affecting smallholder farmers' agroforestry practicing decision in the face of climate variability and change

4.1.3.1.1. Non-causal relationship between smallholder farmers' agroforestry practicing decision and continuous and discontinuous explanatory variables

4.1.3.1.1.1. Non-causal relationship between smallholder farmers' agroforestry practicing decision and continuous explanatory variables

T-test results indicated that there was a significant non-causal relationship between smallholder farmers' agroforestry practicing decision and four continuous explanatory variables (Table 4.10).

The continuous explanatory variables of the study: number of farms ($t = 8.404$, $p<0.001$), household size ($t = 3.800$, $p<0.001$), age of household head ($t = 5.908$, $p<0.001$), and household income ($t = 4.991$, $p<0.001$), all had a significant non-causal relationship with smallholder farmers' agroforestry practicing decision in the face of climate variability and change.

Table 4.10: Independent sample t-test statistic showing non-causal relationship between agroforestry practicing decision and continuous explanatory variables

		Levene's test for the equality of variance		t-test for equality of means			
Variable	**Assumption**	**F**	**p-value**	**t**	**df**	**p-value**	**Mean diff.**
Number of farms	Equal variance assumed	106.453	0.000***				
	Equal variance not assumed			8.404	327.039	0.000***	1.711
Household size	Equal variance assumed	14.555	0.000***				
	Equal variance not assumed			3.800	183.936	0.000***	0.724
Age of household head	Equal variance assumed	21.746	0.000***				
	Equal variance not assumed			5.908	192.126	0.000***	3.344
Annual income of household	Equal variance assumed	38.621	0.000***				
	Equal variance not assumed			4.991	262.955	0.000***	79286.571

******* Significant at 0.1% probability level

Therefore, following the statistics from the t-test; number of farms owned, household size, age of household head, and household income play a plausible role in influencing smallholder farmers' agroforestry practicing decision in the face of climate variability and change.

4.1.3.1.1.2. Non-causal relationship between smallholder farmers' agroforestry practicing decision and discontinuous explanatory variables

Chi-square test results indicated that there was a significant non-causal relationship between smallholder farmers' agroforestry practicing decision in the face of climate variability and change, and seven (07) discontinuous explanatory variables (Table 4.11).

The discontinuous explanatory variables: level of education of household head (X^2 = 25.166, p<0.001), gender of household head (X^2 = 5.354, p<0.05), vulnerability to climate variability and change (X^2 = 27.735, p<0.001), access to information (X^2 = 11.974, p<0.01), access to credit (X^2 = 16.428, p<0.001), access to land (X^2 = 19.133, p<0.001) and access to agricultural extension services (X^2 = 3.778, p<0.05), all had a significant non-causal relationship with smallholder farmers' agroforestry practicing decision in the face of climate variability and change.

Table 4.11: Discontinuous explanatory variables affecting smallholder farmers' agroforestry practicing decision

Discontinuous Variable	Description	Frequency (n)		Percentage (%)		Chi-square	L.R.	p-value
		PAF	NAF	PAF	NAF			
Educational Level	No formal edu.	24	9	6.86	2.57			
	Primary	178	63	50.86	18			
	Secondary	10	0	2.86	0	25.166	40.161	0.000***
	High school	35	0	10	0			
	Tertiary	31	0	8.86	0			
Gender of household head	Male	162	31	46.28	8.86			
	Female	116	41	33.14	11.71	5.354	5.331	0.021**
Vulnerability to CVC	Yes	196	72	56	20.57			
	No	82	0	23.43	0	27.735	43.848	0.000***
Access to information	Yes	48	1	13.71	0.28			
	No	230	71	65.71	20.28	11.974	17.130	0.001***
Access to credit	Yes	67	2	19.14	0.57			
	No	211	70	60.28	20	16.428	22.169	0.000***
Access to land	Yes	61	0	17.43	0			
	No	217	72	62	20.57	19.133	31.277	0.000***
Access to extension	Yes	48	20	13.71	5.71			
	No	230	52	65.71	14.86	4.037	3.778	0.045**

*****, **** Significant at 1% and 5% probability levels respectively; PAF = Practice Agroforestry; NAF = No Agroforestry; L.R. = Likelihood Ratio; info = information

The statistics from the chi-square test therefore confirm that level of education of household head, gender of household head, vulnerability to climate variability and change, access to information, access to credit, access to land and access to agricultural extension services plausibly affect smallholder farmers' agroforestry practicing decision in the face of climate variability and change. Thus, the discontinuous variables: educational level, gender, vulnerability, access to information, access to credit, access to land and access to extension services play a plausible role in influencing smallholder farmers' agroforestry practicing decision faced with climate variability and change.

4.1.3.1.2. Ranking smallholder farmers' practice of agroforestry in the face of climate variability and change according to location

The Kruskall-Wallis test was run to rank the practice of agroforestry and to determine if there was a significant variation in smallholder farmers' practice of agroforestry across ten villages (Mankon, Nkwen, Bambui, Bambili, Kedjom Keku, Mendakwe, Mbei-Santa, Akum, Njong-Santa, and Awing) (Table 4.12).

Table 4.12: Kruskall-Wallis test statistic showing variation in the practice of agroforestry according to village

Village	Frequency (n)		Percentage (%)		Mean Rank	Chi-square	p-level
	Practice Agroforestry	No Agroforestry	Practice AF	No AF			
Mankon	29	11	72.5	27.5	163.38		
Nkwen	31	9	77.5	22.5	172.13		
Bambui	34	6	85	15	185.25		
Bambili	32	8	80	20	176.50		
Kedjom Keku	25	5	83.3	16.7	182.33	5.321	0.805
Mendakwe	26	4	86.7	13.3	188.17	(ns)	
Mbei-Santa	23	7	76.7	23.3	170.67		
Akum	32	8	80	20	176.50		
Njong-Santa	25	5	83.3	16.7	182.33		
Awing	21	9	70	30	159.00		

ns = not significant; AF = Agroforestry

The Kruskall-Wallis test or the H-test indicated that there was no significant variation in the practice of agroforestry in the face of climate variability and change between smallholder farmers across the different villages (X^2 = 5.321, p>0.1). This goes to show that the practice of agroforestry does not vary very significantly across the ten villages studied. However, based on the mean ranks, it is seen that, faced with climate variability and change, smallholder farmers in Mendakwe (mean rank = 188.17), Bambui (mean rank = 185.25), Kedjom Keku (mean rank = 182.33) and Njong-Santa (mean rank = 182.33) are more into agroforestry than their counterparts in Awing (mean rank = 159), Mankon (mean rank = 163.38), Nkwen (mean rank = 172.13), and Mbei-Santa (mean rank = 170.67).

4.1.3.1.3. Causal relationship between smallholder farmers' agroforestry practicing decision faced with climate variability and change, and explanatory variables

The Binary logistic regression model revealed that, there was a significant direct or positive causal relationship between smallholder farmers' agroforestry practicing decision in the face of climate variability and change and five explanatory variables (Table 4.13).

Based on the results of this model, five explanatory variables: age of household head (β = 0.086, p<0.05), household income (β = 1.243, p<0.05), access to information (β = 1.192, p<0.05), access to credit facilities (β = 7.135, p<0.01) and vulnerability to climate variability and change (β = 22.244, p<0.01) had a statistically significant direct causal relationship with smallholder farmers' agroforestry practicing decision.

Table 4.13: Binary logistic regression predicting smallholder farmers' agroforestry practicing decision from eleven explanatory variables

Explanatory variables	Coefficient (β)	p-level	df	Odds ratio (Exp β)
Household size	-0.310**	0.031	1	0.734
Number of farms	0.027	0.880	1	1.028
Age of household head	0.086**	0.048	1	1.090
Household income	1.243**	0.013	1	3.572
Access to extension	-3.107***	0.000	1	0.045
Level of education	0.219	0.657	1	1.245
Gender of HHH	0.149	0.652	1	1.161
Access to information	1.192**	0.028	1	3.295
Access to credit facilities	7.135***	0.000	1	1255.137
Access to land	18.187	0.996	1	79175473.711
Vulnerability to CVC	22.244***	0.000	1	4575583186.46
Constant	22.227	0.995	1	4498948167.405
Number of observations	350			
-2 Log likelihood	253.072			
Likelihood ratio X^2	102.684***	0.000		
Nagelkerke R^2	0.598			
Number of cases correctly classified	84.3%			

, **, ** Significant at 10%, 5% and 1% probability levels respectively

Hence, following the coefficients of the binary logistic regression model; as age, household income, access to information, access to credit facilities and vulnerability increases, there is an increase in smallholder farmers' propensity to practice agroforestry faced with climate variability and change. This could be attributed to the fact that age comes with experience; more income and access to credit facilities gives the farming household more stability and ability to purchase better farm tools; access to information makes farmers more knowledgeable, enabling them to better prepare for extreme weather events; and vulnerability to climate variability and change makes farming households to take to best practices like agroforestry in order to curb their vulnerability.

Meanwhile a strong inverse causal relationship existed between smallholder farmers' agroforestry practicing decision in the face of climate variability and change and two explanatory variables: household size ($\beta = -0.310$, $p<0.05$), and access to agricultural extension services ($\beta = -3.107$, $p<0.001$). This indicates that an increase in household size as well as agricultural extension services leads to a direct proportional reduction in the practice of agroforestry by smallholder farmers in the face of climate variability and change. This could be attributed to the fact that extension services vulgarize mostly monoculture farming

systems, and larger households prefer to go in for monoculture farming systems which brings more food used to feed the large household population.

Although not statistically significant, explanatory variables such as number of farms, educational level of household head, and access to land ($p>0.1$), all had an positive or direct causal relationship with smallholder farmers' agroforestry practicing decision in the face of climate variability and change. This shows that an increase in number of farms, educational level of the household head, and access to land leads to an increase (although not very significant) in smallholder farmers' propensity to practice agroforestry in the face of climate variability and change.

It is important to note that the results of this model are valid looking at the Likelihood Ratio X^2, the number of cases correctly classified, the log likelihood and the pseudo R-square (Nagelkerke R^2). Likelihood Ratio X^2 (11, n = 350 = 102.684, $p<0.001$), indicated that the model was statistically significant and had a strong explanatory power. Meanwhile, the model correctly classified up to 84.3% of smallholder farmers' agroforestry practicing decision faced with climate variability and change. The log likelihood was high (253.072) showing that each of the individual variables contributed significantly to the model. The Pseudo R^2 indicated that at least 59.8% of the changes in smallholder farmers' agroforestry practicing decision faced with climate variability and change resulted from the explanatory variables. From all these, it can be concluded that the predictions of this model are very much valid as far as assessing smallholder farmers' agroforestry decision in the face of climate variability and change is concerned.

4.1.3.2. Categorized agroforestry practices and determinants of smallholder farmers' choice of different agroforestry systems in the face of climate variability and change

4.1.3.2.1. Categorized agroforestry practices of smallholder farmers in the face of climate variability and change

In order to do ease data analysis, the different agroforestry practices identified by smallholder farmers were categorized into three major systems and a fourth category made up of smallholder farmers who did not practice agroforestry (Figure 4.19).

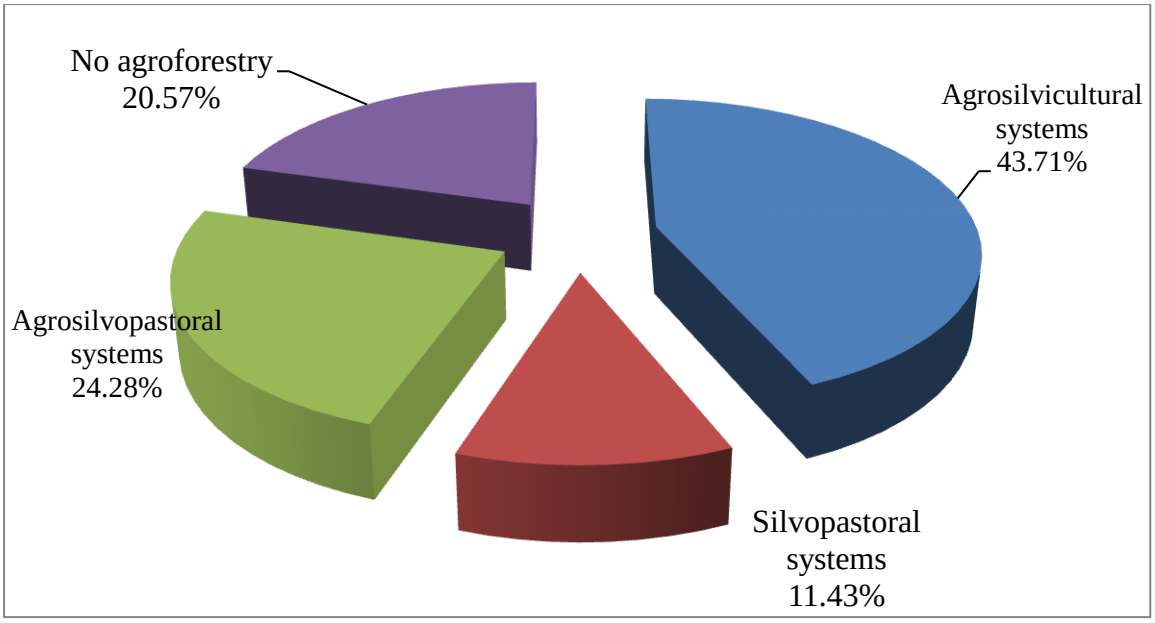

Figure 4.19: Categorized agroforestry practices of smallholder farmers

The three main systems which emerged following the categorization of smallholder farmers' agroforestry practices were the agrosilvicultural system, the silvopastoral system and the agrosilvopastoral system. Amongst these three systems, the agrosilvicultural system was the most commonly identified by smallholder farmers representing 43.71%. This was closely followed by the agrosilvopastoral system identified by 24.28% of the smallholder farmers. The silvopastoral system was the least cited, identified by only 11.43% of the smallholder farmers. This clearly shows that agroforestry practices that fall under the agrosilvicultural system are the most practiced by smallholder farmers in the face of climate variability and change. It is worth noting that some smallholder farmers representing 20.57% were into the no agroforestry option.

4.1.3.2. Determinants of smallholder farmers' choice of different agroforestry systems in the face of climate variability and change

Following the categorization of smallholder farmers' agroforestry practices into agroforestry systems, three main agroforestry systems emerged: agrosilvicultural, silvopastoral, and agrosilvopastoral agroforestry systems. These three agroforestry systems represented the dependent variables, with the "no agroforestry category" representing the reference category. From the parameter estimates of the multinomial logistic regression model, it was found that four (04) explanatory variables played an important role in influencing smallholder farmers' choice of different agroforestry systems in the face of climate variability and change (Table 4.14).

Table 4.14: Parameter estimates of the multinomial logistic regression model showing the causal relationship between agroforestry systems and explanatory variables

Explanatory variables	Agrosilvicultural systems		Silvopastoral systems		Agrosilvopastoral systems	
	Coefficient	p-level	Coefficient	p-level	Coefficient	p-level
Constant	-1.420***	0.000	-0.101	0.813	-0.896**	0.014
Access_information	1.450**	0.019	1.982***	0.007	1.247**	0.047
Access_land	1.208**	0.034	1.294**	0.047	1.909***	0.002
Household income	1.457**	0.017	1.582**	0.009	1.672**	0.007
Access_extension_svs	- 2.395***	0.000	- 2.256***	0.000	- 2.336***	0.000
Access_credit	0.659	0.254	0.519	0.482	- 0.079	0.904
Reference category	No Agroforestry					
Number of observations	350					
Log likelihood	298.64					
Likelihood ratio X^2	165.20***					
Nagelkerke R^2	0.842					

****, ***;** Significant at 5% and 1% probability levels respectively

The parameter estimates of the multinomial logistic regression model showed that three main explanatory variables (access to information, access to land, household income and access to extension services) significantly influenced smallholder farmers' choice of agroforestry systems faced with climate variability and change.

Access to information played a statistically significant role in influencing smallholder farmers' choice of different agroforestry systems (agrosilvicultural, silvopastoral and agrosilvopastoral agroforestry systems). The agrosilvicultural system (a combination of smallholder farmers' agroforestry practices like trees on croplands, home gardens, live fences/hedges, coffee-based agroforestry, Taungya and improved fallows) was directly influenced by access to information ($\beta = 1.450$, $p<0.05$). The silvopastoral system (mostly made up of smallholder farmers' agroforestry practices like trees on grazing lands) was equally significantly influenced by access to information ($\beta = 1.982$, $p<0.01$). The agrosilvopastoral system made up of smallholder farmers' agroforestry practices like home garden with livestock, was also influenced by access to information ($\beta = 1.247$, 0.05). This indicates that access to information contributes significantly towards smallholder farmers' practice of agrosilvicultural, silvopastoral and agrosilvopastoral agroforestry systems faced with climate variability and change. This could be attributed to the fact that access to information influences farmers' access to knowledge about the latest agricultural trends, thus farmers with more knowledge on the latest farming trends are able to tilt towards best

practices which can help them adapt to and mitigate the effects of climate variability and change, than their counterparts with limited knowledge.

Access to land played a very significant role in determining smallholder farmers' choice of agrosilvicultural, silvopastoral and agrosilvopastoral agroforestry systems. Access to land positively influenced smallholder farmers' practice of the agrosilvicultural system ($\beta = 1.208$, $p<0.05$), the silvopastoral system ($\beta = 1.294$, $p<0.05$) and the agrosilvopastoral system ($\beta = 1.909$, $p<0.01$). This indicates that as smallholder farmers' access to land increases, the higher their propensity to take to different agroforestry systems faced with climate variability and change. This state of affairs could be explained by the fact that land is an indispensable asset when it comes to the practice of different agroforestry systems.

Household income had a statistically significant direct causal relationship with smallholder farmers' choice of agroforestry system faced with climate variability and change. Smallholder farmers' choice of the agrosilvicultural agroforestry system ($\beta = 1.457$, $p<0.05$); silvopastoral agroforestry system ($\beta = 1.582$, $p<0.05$) and agrosilvopastoral agroforestry system ($\beta = 1.672$, $p<0.05$) all had a statistically significant positive causal relationship with household income. This indicates that household income plays a significant positive role in influencing smallholder farmers' choice of agroforestry system faced with climate variability and change.

Access to extension services also played a role in affecting smallholder farmers' choice of different agroforestry systems. But contrary to access to information, access to land and household income which positively influenced smallholder farmers' choice of agroforestry systems, access to extension services negatively influenced smallholder farmers' choice of agroforestry systems faced with climate variability and change. Access to extension services negatively influenced smallholder farmers' practice of the agrosilvicultural system ($\beta = -2.395$, $p<0.01$), the silvopastoral system ($\beta = -2.256$, $p<0.01$) and the agrosilvopastoral system ($\beta = -2.336$, $p<0.01$). This is unprecedented considering that various research works have shown that access to extension services increases smallholder farmers' adoption of adaptation measures faced with climate variability and change. This situation could be attributed to the fact that agricultural extension agents mostly promote intensive food crop and market gardening monoculture systems at the expense of agroforestry systems.

Although access to credit facilities did not significantly influence smallholder farmers' choice of agroforestry systems faced with climate variability and change, it positively influenced

smallholder farmers' choice of agroforestry systems. This implies that as access to credit facilities increases, smallholder farmers' propensity to take to different agroforestry systems faced with climate variability and change increases (although less drastically).

It is worth noting that the parameter estimates of the multinomial logistic regression model are valid looking at the Likelihood Ratio X^2 and the Nagelkerke R^2. The Likelihood Ratio X^2 (5, N = 350 = 165.20, $p<0.001$), demonstrated that the model was statistically significant and had a strong explanatory power. From the Nagelkerke R^2 (Pseudo R^2) of the model which was 0.842, it indicated that up to 84.2% of the changes in smallholder farmers' choice of agroforestry systems faced with climate variability and change were explained by changes in the different explanatory variables. Looking at the values of the Likelihood Ratio X^2 and the Nagelkerke R^2, it could be safely concluded that the predictions of this model are very much valid pertaining to the contribution of the different explanatory variables in influencing smallholder farmers' choice of agroforestry systems faced with climate variability and change.

4.1.3.3. Contribution of smallholder farmers' agroforestry practices to the reduction of vulnerability faced with climate variability and change

4.1.3.3.1. Relationship between agroforestry practices and smallholder farmers' vulnerability to climate variability and change

An analysis of the relationship between agroforestry practices and smallholder farmers' vulnerability to climate variability and change revealed that different agroforestry practices except the home garden had a strong inverse relationship with smallholder farmers' vulnerability to climate variability and change (Table 4.15).

Table 4.15: Spearman rank correlation coefficient showing relationship between vulnerability and agroforestry practices

Explanatory variable	Spearman correlation coefficient	Degree and type of relationship
Home garden with livestock	- 0.650***	Strong negative or inverse
Trees on cropland	- 0.707***	Strong negative or inverse
Home garden	0.402	Weak positive or direct
Lives fences/hedges	- 0.857***	Strong negative or inverse
Trees on grazing land	- 0.900***	Strong negative or inverse
Coffee-based agroforestry	- 0.857***	Strong negative or inverse
Taungya	- 0.670***	Strong negative or inverse
Improved fallows	- 0.535***	Strong negative or inverse

******* Significant at 0.1% probability level

Agroforestry practices like the home garden with livestock, trees on cropland, live fences/hedges, trees on grazing land, coffee-based agroforestry, Taungya and improved fallows all had an inverse relationship with smallholder farmers' vulnerability to climate variability and change (Table 4.15). This plausibly implies that the more these agroforestry practices are taken up by smallholder farmers, the lesser their vulnerability to climate variability and change. Only the home garden had a direct relationship (although weak) with smallholder farmers' vulnerability. This could be due to the absence of the livestock component. Globally, it can therefore be said that agroforestry practices play a plausible role in reducing smallholder farmers' vulnerability to climate variability and change.

4.1.3.3.2. Non-causal relationship between agroforestry practices and smallholder farmers' vulnerability to climate variability and change

Chi-square test results showed that eight (08) agroforestry practices significantly affected smallholder farmers' vulnerability to climate variability and change ($p<0.01$) (Table 4.16).

Table 4.16: Chi-square test results for agroforestry practices affecting smallholder farmers' vulnerability to climate variability and change

Variable	Description	Frequency (n)		Percentage (%)		Chi-square	L.R.	p-value
		V.	N.V.	V.	N.V.			
Home garden with livestock	Yes	65	82	18.57	23.43			
	No	203	0	58	0	147.89	179.27	0.000***
Trees on croplands	Yes	51	82	14.57	23.43			
	No	217	0	62	0	174.72	203.10	0.000***
Home garden	Yes	121	0	34.57	0			
	No	82	147	23.43	42	56.58	82.33	0.000***
Live fences/ hedges	Yes	21	82	6	23.43			
	No	247	0	70.57	0	256.81	276.90	0.000***
Trees on grazing land	Yes	14	82	4	23.43			
	No	254	0	72.57	0	283.34	301.32	0.000***
Coffee-based agroforestry	Yes	9	73	2.57	20.86			
	No	259	9	74	2.57	256.85	245.55	0.000***
Taungya	Yes	4	47	1.14	13.43			
	No	264	35	75.43	10	157.19	137.15	0.000***
Improved fallows	Yes	3	32	0.86	9.14			
	No	265	50	75.71	14.29	100.24	84.94	0.000***

******* Significant at 0.1% probability level; V. = vulnerable; N.V. = Not vulnerable; L.R. = Likelihood Ratio

Amongst the different agroforestry practices, home gardens with livestock (X^2 = 147.89, $p<0.001$), trees on croplands (X^2 = 174.72, $p<0.001$), home garden (X^2 = 56.58, $p<0.001$), life

fences/hedges (X^2 = 256.81, p<0.001), trees on grazing lands (X^2 = 283.34, p<0.001), coffee-based agroforestry (X^2 = 256.85, p<0.001), Taungya (X^2 = 157.19, p<0.001), and improved fallows (X^2 = 100.24, p<0.001) all had a significant non-causal relationship with smallholder farmers' vulnerability to climate variability and change. From every indication, it can be said that agroforestry practices like home gardens with livestock, trees on croplands, home garden, life fences/hedges, trees on grazing lands, coffee-based agroforestry, Taungya, and improved fallows all play a plausibly significant role in influencing smallholder farmers' vulnerability to climate variability and change.

4.1.3.3.3. Causal relationship between agroforestry practices and smallholder farmers' vulnerability faced with climate variability

The Binary logistic regression model indicated that there was a causal relationship between agroforestry practices and smallholder farmers' vulnerability to climate variability and change (Table 4.17).

Table 4.17: Binary logistic regression model predicting smallholder farmers' vulnerability from agroforestry practices

Explanatory variable	Coefficients	p-level	Odds ratio (Exp B)
Constant	-3.143***	0.000	0.043
Home garden with livestock	-3.482***	0.008	0.030
Trees on croplands	-4.673***	0.000	0.009
Home garden	3.099**	0.027	22.175
Live fences/hedges	-0.486	0.542	0.615
Trees on grazing lands	-1.674**	0.037	0.187
Coffee-based agroforestry	-2.331***	0.009	0.097
Taungya	-1.462**	0.041	0.231
Improved fallows	-0.245	0.856	0.782
Number of observations	350		
-2 log likelihood	89.431		
Likelihood ration X^2	192.245***	0.000	
Pseudo R^2	0.967		

*****, **** Significant at 1% and 5%probability levels respectively

From the estimates of this model, five agroforestry practices: home garden with livestock (β = -3.482, p<0.01), Trees on croplands (β = -4.673, p<0.01), trees on grazing lands (β = -1.674, p<0.05), coffee-based agroforestry (β = -2.331, p<0.01), Taungya (β = -1.462, p<0.05) had a statistically significant negative or indirect causal relationship with smallholder farmers' vulnerability faced with climate variability and change. This goes to show that an increase in agroforestry practices like home gardens with livestock, trees on croplands, trees

on grazing lands, coffee-based agroforestry and Taungya leads to a significant reduction in smallholder farmers' vulnerability faced with climate variability and change. This could be attributed to the crop, tree and livestock components present in these practices which help to increase diversity and therefore diversify smallholder farmers' sources of income too.

Only one agroforestry practice i.e. the home garden ($\beta = 3.099$, $p<0.01$), had a significant positive causal relationship with smallholder farmers' vulnerability faced with climate variability and change. This indicates that as the practice of home garden increases, smallholder farmers' vulnerability to climate variability and change also increases. This could be attributed to the absence of the livestock component which plays an important role in income generation and diversification of income sources for smallholder farmers.

Although the coefficients of agroforestry practices like live fences/hedges and improved fallows were not statistically significant, they nevertheless had an indirect or negative causal relationship with smallholder farmers' vulnerability to climate variability and change. This implies that an increase in agroforestry practices like live fences/hedges and improved fallows leads to a reduction (though not too statistically significant) in smallholder farmers vulnerability to climate variability and change.

The contribution of these different agroforestry practices towards the reduction of smallholder farmers' vulnerability faced with climate variability and change could be attributed to the different products and services provided by these agroforestry practices: food, fuelwood, building materials, windbreaks, erosion control, and soil fertility improvement.

It is worth mentioning that the results of this model are valid looking at the Likelihood Ratio X^2, the number of cases correctly classified and the Nagelkerke R^2. Likelihood Ratio X^2 (8, N = 350 = 192.245, $p<0.001$), indicated that the model was statistically significant and had a strong explanatory power. Meanwhile, following the classification table of the model, the model correctly classified up to 97.62% of smallholder farmers' vulnerability face with climate variability and change. And looking at the Nagelkerke R^2 (Pseudo R^2) of the model which was 0.967, it demonstrated that up to 96.7% of the changes in smallholder farmers' vulnerability faced with climate variability and change were explained by changes in smallholder farmers' agroforestry practices. From the values of the Likelihood Ratio X^2, the number of cases correctly classified and the Nagelkerke R^2, it can be safely concluded that the predictions of this model are very much valid as far as the contribution of agroforestry

practices in reducing smallholder farmers' vulnerability to climate variability and change is concerned.

4.1.4. Agroforestry practices and smallholder farmers' resilience faced with climate variability and change

4.1.4.1. Farmer perceived factors affecting resilience to climate variability and change

Looking at smallholder farmers' resiliency to climate variability and change (CVC) (Figure 4.20), it was found that all the smallholder farmers perceived access to land (100%) and household income (100%) as being the main factors affecting resilience to climate variability and change.

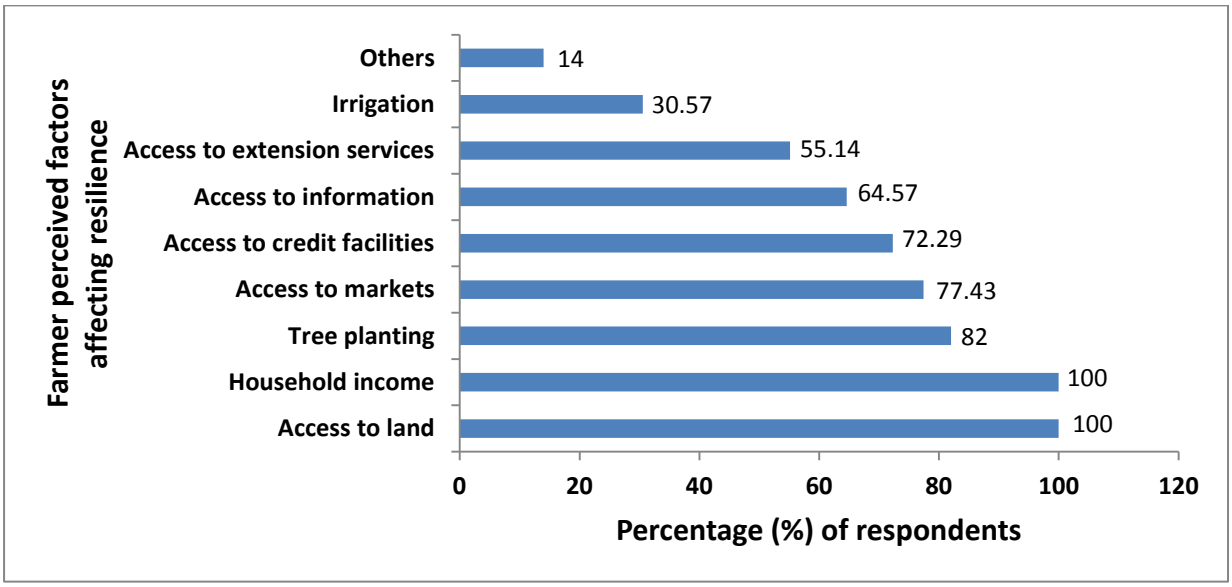

Figure 4.20: Factors affecting resilience to climate variability and change perceived by smallholder farmers

Tree planting (82%), accessibility to markets (77.43%), access to credit facilities (72.29%), access to information (64.57%) and access to extension services (55.14) were equally perceived by smallholder farmers as being amongst the key factors affecting resilience to climate variability and change. Other least perceived factors influencing resiliency to climate variability and change were irrigation (30.57%) and others (14%) like road network and topography. However, it is worth mentioning that the main factors influencing smallholder farmers' resilience to climate variability and change were access to land, household income, trees on crop and grazing lands, accessibility to markets, access to credit facilities, and access to information (Figure 4.20).

4.1.4.2. Farmer perceived degree or level of resilience in the face of climate variability and change

With regards to the degree of resilience of smallholder farmers in the face of climate variability and change (Figure 4.21), most smallholder farmers perceived that they were not resilient (58%).

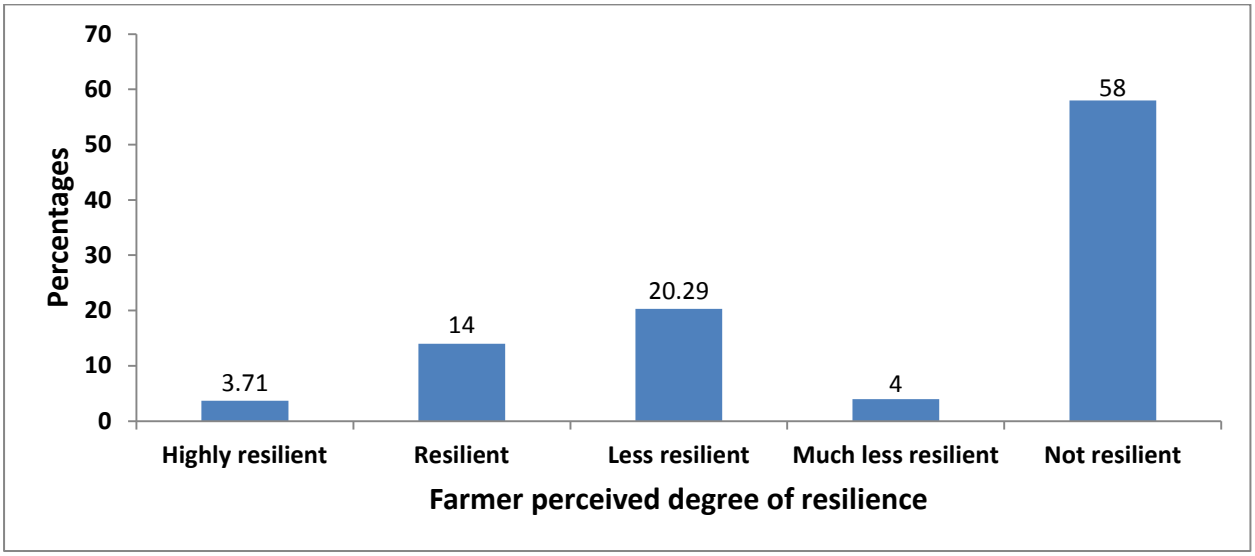

Figure 4.21: Degree of resilience to climate variability and change perceived by smallholder farmers

Meanwhile 14%, 20.29% and 4% of the smallholder farmers perceived that they were resilient, less resilient and much less resilient to climate variability and change respectively. Only 3.71% of the smallholder farmers perceived that they were highly resilient to climate variability and change. From these perceptions, it is vivid that most smallholder farmers are not resilient to climate variability and change (Figure 4.21).

4.1.4.3. Factors affecting smallholder farmers' resilience to climate variability and change

4.1.4.3.1. Non-causal relationship between continuous explanatory variables and smallholder farmers' resilience to climate variability and change

T-test results showed that there was a significant non-causal relationship between smallholder farmers' resilience and four continuous explanatory variables (Table 4.18).

The continuous explanatory variables of the study: number of farms ($t = 10.776$, $p<0.001$), household size ($t = 7.552$, $p<0.001$), age of household head ($t = 8.224$, $p<0.001$), and household income ($t = 9.062$, $p<0.001$), all had a significant non-causal relationship with smallholder farmers' resilience in the face of climate variability and change.

Table 4.18: Independent sample t-test statistic showing the non-causal relationship between resilience and continuous explanatory variables

		Levene's test for the equality of variance		**t-test for equality of means**			
Variable	**Assumption**	**F**	**p-level**	**t**	**df**	**p-level**	**Mean diff.**
Number of farms	Equal variance assumed	502.094	0.000***				
	Equal variance not assumed			-10.776	170.493	0.000***	-2.940
Household size	Equal variance assumed	107.704	0.000***				
	Equal variance not assumed			-7.552	195.262	0.000***	-1.590
Age of household head	Equal variance assumed	83.806	0.000***				
	Equal variance not assumed			-8.224	209.441	0.000***	-5.192
Household income	Equal variance assumed	150.556	0.000***				
	Equal variance not assumed			-9.062	179.442	0.000***	-179415.9

******* Significant at 0.1% probability level

From the statistics of the t-test, it was found that: number of farms owned, household size, age of household head, and household income plausibly affect smallholder farmers' resilience to climate variability and change.

4.1.4.3.2. Non-causal relationship between discontinuous explanatory variables and smallholder farmers' resilience to climate variability and change

Chi-square test results showed that there was a significant non-causal relationship between smallholder farmers' resilience to climate variability and change, and seven (07) discontinuous explanatory variables (Table 4.19).

The discontinuous explanatory variables: level of education of household head (X^2 = 123.10, p<0.001), gender of household head (X^2 = 24.95, p<0.001), practice of agroforestry (X^2 = 64.50, p<0.001), access to information (X^2 = 44.70, p<0.001), access to credit (X^2 = 90.88, p<0.001), access to land (X^2 = 52.50, p<0.001) and access to agricultural extension services (X^2 = 21.54, p<0.001), all had a significant non-causal relationship with smallholder farmers' resilience to climate variability and change.

Table 4.19: Chi-square test statistic showing the non-causal relationship between resilience and discontinuous explanatory variables

Discontinuous Variable	**Description**	**Frequency (n)**		**Percentage (%)**		**Chi-square**	**L.R.**	**p-level**
		R.	**N.R.**	**R.**	**N.R.**			
Educational Level of household head	No formal edu.	11	21	3.14	6	123.10	141.69	0.000***
	Primary	62	180	17.71	51.43			
	Secondary	10	0	2.86	0			
	High school	34	1	9.71	2.86			
	Tertiary	30	1	8.57	2.86			
Gender of household head	Male	104	89	29.71	25.43	24.95	25.47	0.000***
	Female	43	114	12.28	32.57			
Practice Agroforestry	Yes	147	132	42	37.71	64.50	90.23	0.000***
	No	0	71	0	20.28			
Access to information	Yes	42	7	12	2	44.70	46.69	0.000***
	No	105	196	30	56			
Access to credit	Yes	64	5	18.28	1.43	90.88	99.25	0.000***
	No	83	198	23.71	56.57			
Access to land	Yes	51	10	14.57	2.86	52.50	54.33	0.000***
	No	96	193	27.43	55.14			
Access to extension	Yes	45	22	12.86	6.29	21.54	21.41	0.000***
	No	102	181	29.14	51.71			

******* Significant at 0.1% probability level; R. = Resilient; N.R. = Not Resilient; L.R. = Likelihood Ratio; info. = information; edu. = education

Based on the chi-square statistics; level of education of household head, gender of household head, practice of agroforestry, access to information, access to credit, access to land and access to agricultural extension services could plausibly affects smallholder farmers' resilience to climate variability and change.

4.1.4.3.3. Causal relationship between explanatory variables and smallholder farmers' resilience to climate variability and change

The results of the binary logistic regression model revealed that five main explanatory variables played a statistically significant role in influencing smallholder farmers' resilience to climate variability and change (Table 4.20).

From the results of the model, number of farms ($\beta = 0.271$, $p<0.05$), access to information ($\beta = 0.937$, $p<0.1$), household income ($\beta = 1.821$, $p<0.05$), access to credit facilities ($\beta = 1.596$, $p<0.05$), and access to land ($\beta = 1.029$, $p<0.05$) all had a significant positive causal relationship with smallholder farmers' resilience to climate variability and change. This implies that as the number of farms, access to information, household income, access to credit facilities, and access to land increases, smallholder farmers' resilience to climate variability and change also increases.

Table 4.20: Logistic regression showing influence of continuous and discontinuous explanatory variables on smallholder farmers' resilience to climate variability and change

Explanatory variables	Coefficients (β)	p-level	Std error	Wald	df	Odds ratio (Exp β)
Constant	- 1.961***	0.000	0.294	44.426	1	0.141
Number of farms	0.271**	0.003	0.092	8.690	1	1.311
Household income	1.821	0.002	0.614	9.064	1	5.134
Access to information	0.937*	0.087	0.548	2.929	1	2.553
Access to credit facilities	1.596**	0.006	0.582	7.526	1	4.931
Access to land	1.029**	0.027	0.465	4.891	1	2.798
Log likelihood	330.37					
Likelihood ratio X^2	145.84***	0.000				
Nagelkerke R^2	0.648					
Number of cases correctly classified	80%					

, **, ** Significant at 10%, 5% and 1% probability levels respectively

It is important to note that the results of this model are valid looking at the Likelihood Ratio X^2, the number of cases correctly classified and the Nagelkerke R^2. Likelihood Ratio X^2 (5, n = 350 = 145.835, $p<0.01$), indicated that the model was statistically significant and had a strong explanatory power. Meanwhile, the model correctly classified up to 80% of the factors influencing smallholder farmers' resilience to climate variability and change. And looking at

the Nagelkerke R^2 (Pseudo R^2) of the model which stood at 0.648, it reveals that up to 64.8% of the changes in smallholder farmers' resilience to climate variability and change could be explained by changes in the continuous and discontinuous explanatory variables of the model. Hence, from the values of the Likelihood Ratio X^2, the number of cases correctly classified and the Nagelkerke R^2, it can be concluded that the predictions of this model are very much valid as far as determining the factors influencing smallholder farmers' resilience to climate variability and change are concerned.

4.1.4.4. Contribution of smallholder farmers' agroforestry practices to resilience enhancement in the face of climate variability and change

4.1.4.4.1. Non-causal relationship between agroforestry practices and smallholder farmers' resilience to climate variability and change

Chi-square test results showed that there was a significant non-causal relationship between smallholder farmers' resilience to climate variability and change and seven (07) agroforestry practices (Table 4.21).

Table 4.21: Chi-square test statistic showing the non-causal relationship between resilience and agroforestry practices

Variable	Description	Frequency (n)		Percentage (%)		Chi-square	L.R.	p-value
		R.	N.R.	R.	N.R.			
Home garden with livestock	Yes	99	49	28.28	14			
	No	48	154	13.71	44	65.22	66.74	0.000***
Trees on croplands	Yes	92	41	26.29	11.71			
	No	55	162	15.71	46.29	65.02	66.21	0.000***
Home garden	Yes	46	75	13.14	21.43			
	No	101	128	28.86	36.57	1.20	1.21	ns
Live fences/ hedges	Yes	84	19	24	5.43			
	No	63	184	18	52.57	93.73	97.21	0.000***
Trees on grazing land	Yes	84	12	24	3.43			
	No	63	191	18	54.57	112.42	119.30	0.000***
Coffee-based agroforestry	Yes	74	8	21.14	2.28			
	No	73	195	20.86	55.71	102.32	109.88	0.000***
Taungya	Yes	45	6	12.86	1.71			
	No	102	197	29.14	56.29	52.39	55.47	0.000***
Improved fallows	Yes	31	4	8.86	1.14			
	No	116	199	33.14	56.86	34.62	36.77	0.000***

******* Significant at 0.1% probability level; ns = not significant; R. = Resilient; N.R. = Not Resilient; L.R. = Likelihood Ratio

The agroforestry practices: home garden with livestock (X^2 = 65.22, p<0.001), trees on croplands (X^2 = 65.02, p<0.001), live fences/hedges (X^2 = 93.73, p<0.001), trees on grazing lands (X^2 = 112.42, p<0.001), coffee-based agroforestry (X^2 = 102.32, p<0.001), Taungya (X^2 = 52.39, p<0.001) and improved fallows (X^2 = 34.62, p<0.001), all had a significant non-causal relationship with smallholder farmers' resilience to climate variability and change. Only the home garden did not have a statistically significant non-causal relationship with smallholder farmers' resilience to climate variability and change. This demonstrates smallholder farmers' agroforestry practices like home garden with livestock, trees on croplands, live fences/hedges, trees on grazing lands, coffee-based agroforestry, Taungya and improved fallows plausibly influence smallholder farmers' resilience to climate variability and change.

4.1.4.4.2. Causal relationship between agroforestry practices and smallholder farmers' resilience to climate variability and change

The results of the binary logistic regression model revealed that four major agroforestry practices played a statistically significant role in enhancing smallholder farmers' resilience to climate variability and change (Table 4.22).

Table 4.22: Logistic regression showing influence of agroforestry practices on smallholder farmers' resilience to climate variability and change

Explanatory variables	Coefficients (β)	p-level	Std error	Wald	df	Odds ratio (Exp β)
Constant	- 3.780***	0.000	0.728	26.935	1	0.023
Home gardens with livestock	3.158***	0.000	0.779	16.422	1	23.514
Home gardens	3.189***	0.000	0.756	17.795	1	24.256
Trees on croplands	- 0.452	0.291	0.428	1.116	1	0.636
Trees on grazing lands	1.663**	0.001	0.487	11.677	1	5.276
Live fences/hedges	0.210	0.115	0.619	0.115	1	0.735
Coffee-based agroforestry	2.771**	0.006	1.000	7.677	1	15.980
Taungya	- 1.626	0.168	1.180	1.898	1	0.197
Improved fallows	0.340	0.717	0.937	0.132	1	1.405
Log likelihood	300.15					
Likelihood ratio X^2	176.055***	0.000				
Nagelkerke R^2	0.532					
Number of cases correctly classified	77.7%					

****, ***** Significant at 5% and 1% probability levels respectively

From the results of the model, home gardens with livestock (β = 3.158, p<0.01), home gardens (β = 3.189, p<0.01), trees on grazing lands (β = 1.663, p<0.05), and coffee-based agroforestry (β = 2.771, p<0.05) all had a significant positive causal relationship with smallholder farmers' resilience to climate variability and change. This implies that as home gardens with livestock, home gardens, trees on grazing lands and coffee-based agroforestry increases, smallholder farmers' resilience to climate variability and change also increases. Meanwhile live fences/hedges and improved fallows, although not statistically significant (p>0.1), also had a positive causal relationship with smallholder farmers' resilience to climate variability and change. This implies that an increase in live fences and hedges, as well as improved fallows leads to an increase in smallholder farmers' resilience to climate variability and change. On the contrary, trees on croplands and Taungya, although not statistically significant (p>0.1) had a negative causal relationship with smallholder farmers' resilience to climate variability and change. This implies that the practice of these two agroforestry practices leads to a decrease in smallholder farmers' resilience to climate variability and change.

It must be said that the results of this model are valid looking at the Nagelkerke R^2 of the model which is above the 50% mark (53.2%), Likelihood Ratio X^2, and the number of cases correctly classified. The Likelihood Ratio X^2 (8, n = 350 = 176.055, p<0.01), indicated that the model was statistically significant and had a strong explanatory power. Meanwhile, the model correctly classified up to 77.7% of the agroforestry practices influencing smallholder farmers' resilience. The Nagelkerke R^2 of the model which stood at 0.532 implies that 53.2% of the changes in smallholder farmers' resilience to climate variability and change could be explained by changes in the different agroforestry practices. From all these, it can be concluded that the predictions of this model are very much valid as far as determining the different agroforestry practices influencing smallholder farmers' resilience to climate variability and change is concerned.

4.1.4.4.3. Variations in resilience according to location

The Kruskall-Wallis test was run to rank smallholder farmers' resilience to climate variability and change, and to determine if there was a significant variation in smallholder farmers' resilience across ten villages in the North-West Region of Cameroon (Mankon, Nkwen, Bambui, Bambili, Kedjom Keku, Mendakwe, Mbei-Santa, Akum, Njong-Santa, and Awing) (Table 4.23).

Based on the mean ranks of the Kruskall-Wallis test **(**H-test), it was noticed that in the face of climate variability and change, smallholder farmers in Mendakwe (mean rank = 189.50), Mbei-Santa (mean rank = 189.50), Kedjom Keku (mean rank = 183.67) and Njong-Santa (mean rank = 183.67) were more resilient than their counterparts in Mankon (mean rank = 145.73), Bambili (mean rank = 167.63), Nkwen (mean rank = 172), and Bambui (mean rank = 176.38). However, the H-test statistic indicated that there was no statistically significant variation in smallholder farmers' resilience to climate variability and change across the different villages (X^2 = 7.409, p>0.05).

Table 4.23: Kruskall-Wallis test statistic showing variations in resilience according to village

Village	Frequency (n)		Percentage (%)		Mean Rank	Chi-square	p-level
	Resilient	Not Resilient	Resilient	Not Resilient			
Mankon	10	30	25	75	145.75		
Nkwen	16	24	40	60	172.00		
Bambui	17	23	42.5	57.5	176.38		
Bambili	15	25	37.5	62.5	167.63		
Kedjom Keku	14	16	46.67	53.33	183.67	7.409	0.595
Mendakwe	15	15	50	50	189.50		(ns)
Mbei-Santa	15	15	50	50	189.50		
Akum	18	22	45	55	180.75		
Njong-Santa	14	16	46.67	53.33	183.67		
Awing	13	17	43.33	56.67	177.83		

ns = not significant

The statistics of the H-test indicated that smallholder farmers' resilience to climate variability and change did not vary significantly across the ten villages under study. It could therefore be concluded that smallholder farmers' resilience to climate variability and change is not dependent on the village of the farmers'.

4.1.4.4.4. Agroforestry systems and smallholder farmers' resilience to climate variability and change

The Kruskall-Wallis (H) test was run to rank smallholder farmers' resilience to climate variability and change according to the agroforestry systems they practiced and to determine if there was a significant variation in smallholder farmers' resilience based on these agroforestry systems (Table 4.24).

Table 4.24: Kruskall-Wallis test statistic showing variations in resilience according to agroforestry system practiced.

Agroforestry system	Frequency (n)		Percentage (%)		Mean Rank	Chi-square	p-level
	Resilient	Not Resilient	Resilient	Not Resilient			
Agrosilvicultural	71	82	20.28	23.43	183.21		
Silvopastoral	17	23	4.86	6.57	176.38		
Agrosilvopastoral	40	46	11.43	13.14	183.40	8.686	0.034**
No agroforestry (reference category)	19	52	5.43	14.86	148.83		

****** Significant at 5% probability level

From the mean ranks of the Kruskall-Wallis test or the H-test, it was found that smallholder farmers who were into the agrosilvicultural (mean rank = 183.21) and agrosilvopastoral (mean rank = 183.40) agroforestry systems were more resilient to climate variability and change than their counterparts who were into the silvopastoral (mean rank = 176.38) agroforestry system. The least resilient to climate variability and change were smallholder farmers who were into the "No Agroforestry" option (mean rank = 148.83).

The H-test statistic showed that there was a statistically significant variation in smallholder farmers' resilience to climate variability and change according to the different agroforestry systems (X^2 = 8.686, p<0.05). This indicates that smallholder farmers' resilience to climate variability and change varies in relation to the different agroforestry systems practiced. It can therefore be concluded that smallholder farmers' resilience to climate variability and change is highly influenced by the agroforestry systems they practice.

4.2. DISCUSSION OF RESULTS

4.2.1. Drivers of smallholder farmers' vulnerability to climate variability and change

Literature is replete with studies carried out across Cameroon, Africa and the tropics, highlighting the causes of smallholder farmers' vulnerability to climate variability and change (Molua and Lambi, 2002; Gbetibouo, 2009; Deressa *et al.*, 2011; Tabi *et al.*, 2012; Yaro, 2013; Rurinda, 2014; Rurinda *et al.*, 2014; Awazi, 2016; Awazi and Tchamba, 2018). However, very few research works have examined the drivers of smallholder farmers' vulnerability to climate variability and change in an in-depth and holistic manner, and employing quantitative techniques. It was within this framework that this study sought to fill this knowledge gap. Based on the findings of the study, three broad categories of variables

i.e. climate-related, socio-economic and institutional variables were the main drivers of smallholder farmers' vulnerability to climate variability and change.

With respect to climate-related variables driving smallholder farmers' vulnerability to climate variability and change, it was noticed that two climate parameters – temperature and rainfall, were the main variables driving vulnerability. With high levels of fluctuation in temperature and rainfall in the past five decades, smallholder farmers increasingly find it difficult to plan for the farming season. Farmers' local knowledge about weather trends has been hampered by high levels of fluctuation in rainfall and temperature in particular, and other extreme weather events, making it near impossible for farmers to know the start and the end of the farming season (onset and cessation of the rainy season). Although several studies carried out in rural Cameroon in general and Mezam division in particular have demonstrated high levels of variability in climate parameters (temperature and rainfall in particular) in recent years (Kimengsi and Azibo, 2015; Gur *et al.,* 2015; Awazi, 2016; Azibo *et al.,* 2016; Innocent *et al.,* 2016; Kimengsi and Botanga, 2017; Tume, 2019; Tume *et al.,* 2019a; Tume *et al.,* 2019b; Bate *et al.,* 2019; Awazi *et al.,* 2019), little or no research has been conducted demonstrating that variations and changes in climate parameters are a major cause of smallholder farmers' vulnerability to climate variability and change. Equally, although research studies carried out in other parts of the world (Chen and Wang, 1995; Buishand and Brandsman, 1999; Saleshi and Zanke, 2004; Cong and Brady, 2012; Berg *et al.,* 2013; Olsson *et al.,* 2015; Nkuna and Odiyo, 2016; Weng *et al.,* 2017) have demonstrated the existence of a plausible non-causal and causal relationship between climate parameters (temperature, rainfall, and rainy days) in the present dispensation of climate variability and change, little or no research has been carried out in Cameroon in general and the North-West Region of Cameroon in particular, examining the relationship that exists between climate parameters in the face of climate variability and change. These knowledge gaps have been fully addressed in this study.

Pertaining to socio-economic and institutional variables driving smallholder farmers' vulnerability to climate variability and change, a number of studies carried out across Cameroon and Africa have examined some of these variables as drivers of vulnerability (Molua and Lambi, 2002; Smit and Wandel, 2006; Challinor *et al.,* 2007; Gbetibouo and Ringler, 2009; Tabi *et al.,* 2012; Kasulo *et al.,* 2012; Belaineh *et al.,* 2013; Kuwornu *et al.,* 2013; Tessema *et al.,* 2013; Burney *et al.,* 2014; Temesgen *et al.,* 2014; Rurinda, 2014;

Rurinda *et al.,* 2014; Harvey *et al.,* 2014; Feleke, 2015; Kirui *et al.,* 2015; Awazi, 2016; Kimengsi and Botanga, 2017; Fongnzossie *et al.,* 2018; Awazi and Tchamba, 2018). It must however be said that most of these studies either tackled smallholder farmers' vulnerability to climate variability and change very superficially, or employed mainly descriptive, qualitative and conceptual approaches to assess smallholder farmers' vulnerability faced with climate variability and change. This study is one of the first to be done in Cameroon in general and the North-West Region of Cameroon in particular, that significantly employed quantitative techniques (inferential statistics like the T-test, Chi-square, Spearman rank correlation, and the binary logistic regression) to demonstrate the role of socio-economic and institutional variables in driving smallholder farmers' vulnerability to climate variability and change. Findings indicated that a non-causal and causal relationship existed between socio-economic and institutional variables, and smallholder farmers' vulnerability to climate variability and change. Thus, socio-economic and institutional variables such as number of farms, household size, age of household head, household income, level of education, gender, practice of agroforestry, access to information, access to credit, access to land, and access to extension services, which all had a statistically significant non-causal relationship with smallholder farmers' vulnerability, plausibly affect smallholder farmers' vulnerability to climate variability and change. Meanwhile socio-economic and institutional variables such as household size, age of household head, household income, access to information, and access to land which had a statistically negative causal relationship with smallholder farmers' vulnerability, play a great role in reducing smallholder farmers' vulnerability to climate variability and change. The existence of a strong negative causal relationship between these socio-economic and institutional variables (household size, age of household head, household income, access to information, and access to land), and smallholder farmers' vulnerability to climate variability and change could be due to several reasons: firstly, household size is synonymous to labour force (especially in village settings). Thus, the bigger the household, the bigger the labour force, which enables the family to farm a larger farm plot, which everything being equal results in more output, thus ensuring food security. Age of household head on its part is associated with farm experience. Thus, the older the household head, the more experienced he/she is, which implies better mastery of the environment and cropping seasons. Household income enables farmers to buy better farm inputs, equipments and even food, implying that households with more income are much less vulnerable to the adverse effects of climate variability and change. Access to information on its part helps to strengthen smallholder farmers' decision making abilities. Farmers with more information are more

knowledgeable about the latest trends in the farming sector and therefore take to better farming practices, and apply better farm inputs than their counterparts with less information. Moreover, access to land is vital because land is a major asset indispensable to farming activities. Thus, farmers with more land are able to cultivate a diversity of crops which helps to spread risk. The aforementioned socio-economic and institutional variables therefore play a key role in reducing vulnerability to climate variability and change.

Hence, contrary to other studies which assessed drivers of smallholder farmers' vulnerability to climate variability and change only superficially, or employed mainly descriptive, qualitative and conceptual approaches to assess smallholder farmers' vulnerability, this study makes use of mainly quantitative or inferential techniques, bringing to the limelight, the causal and non-causal relationship existing between climate, socio-economic and institutional explanatory variables, and smallholder farmers' vulnerability to climate variability and change. Thus, climate, socio-economic and institutional explanatory variables are the main drivers of smallholder farmers' vulnerability to climate variability and change in Mezam division in particular and the North-West Region of Cameroon in general.

4.2.2. Characterized agroforestry practices of smallholder farmers faced with climate variability and change

Studies carried out across different parts of Cameroon, Africa and the tropics have generally classified agroforestry practices on the basis of structure, function, socio-economic attributes, and ecological attributes into a plethora of agroforestry systems (Nair, 1985; Nair, 1993; Nair *et al.,* 2004; Nair and Garrity, 2012; Atangana *et al.,* 2014; Montagnini, 2017; Amare *et al.,* 2018; Awazi and Avana, 2019). Thus, the agroforestry practices of smallholder farmers have merely been characterized generally by most studies (Raintree and Torres, 1986; Raintree and Warner, 1986; Pandey, 2007; Snelder and Lasco, 2008; Focho *et al.,* 2009; Asaah *et al.,* 2011; Temgoua, 2011; Kumar and Nair, 2012; Dagar and Tewari, 2017; Coulibaly *et al.,* 2017; Njongue *et al.,* 2017; Munjeb *et al.,* 2018; Tsufac *et al.,* 2019). However, the peculiarity of this study lies in the fact that it sought to characterize the agroforestry practices of smallholder farmers in the face of climate variability and change. Based on this, three main agroforestry systems (agrosilvicultural, silvopastoral, and agrosilvopastoral) and eleven main agroforestry practices (home garden, trees on cropland, live fences/hedges, Taungya, coffee-based agroforestry, improved fallows, windbreaks, trees on grazing lands, fodder banks, home gardens with livestock, and trees on grazing lands with crops) were unearthed.

Although some studies carried out across Cameroon, Africa and the tropics (Molua, 2005; Syampungani *et al.,* 2010; Rao *et al.,* 2011; Asfaw and Lemenih, 2012; Bishaw *et al.,* 2013; Charles *et al.,* 2013; Mbow *et al.,* 2013b; Mbow *et al.,* 2014; De Zoysa and Inoue, 2014; Kabir *et al.,* 2015; Kumar, 2016; Negawo and Beyene, 2017; Awazi and Tchamba, 2019) have attempted to classify the agroforestry practices/systems used by smallholder farmers to adapt to and mitigate the impacts of climate variability and change, most of the research was superficial, descriptive, conceptual and mostly based on a review of literature. Studies conducted in Cameroon in general and the North-West Region of Cameroon in particular have done little or nothing to characterize smallholder farmers' agroforestry practices faced with climate variability and change. A review of literature found that just Awazi (2016) and Awazi *et al.* (2019) conducted some research (although very superficial) assessing smallholder farmers' adaptation options (agroforestry being one of the adaptation options) faced with climate variability and change in Mbengwi Central sub-division, the North-West Region of Cameroon. The findings of this study have therefore come in to fill this knowledge vacuum.

Moreover, the study quantified the ecosystem services derived from smallholder farmers' agroforestry practices; the main classes of agroforestry tree/shrub species integrated on smallholder farmers' agroforestry farm plots; the food and cash crop species integrated on smallholder farmers' agroforestry plots; common livestock species reared by smallholder farmers practicing agroforestry; and common tree/shrub species integrated within smallholder farmers' agroforestry plots; in the face of climate variability and change. Hence, faced with climate variability and change, smallholder farmers take to a plethora of agroforestry practices, within which they integrate a diversity of food and cash crops; livestock; and trees/shrubs species in order to obtain the five "Fs" (Food, fodder, fuelwood, finance and soil fertility improvement) which helps them reduce vulnerability and enhance resilience to climate variability and change. This study is therefore one of the first to do a broad-based characterization of agroforestry practices taken up by smallholder farmers in Cameroon in general and the North-West Region of Cameroon in particular, in the face of climate variability and change.

4.2.3. Smallholder farmers' agroforestry practices and vulnerability to climate variability and change

Here, the study sought to examine the determinants of smallholder farmers' practice of agroforestry faced with climate variability and change; and to assess the contributions of different agroforestry practices to the reduction of smallholder farmers' vulnerability to climate variability and change.

First and foremost, with regards to the determinants of smallholder farmers' practice of agroforestry faced with climate variability and change, it was found that little or nothing has been done in this direction in Cameroon in general and the North-West Region of Cameroon in particular. Although some studies have been carried out on agroforestry systems in Cameroon (Asaah *et al.,* 2011; Temgoua, 2011; Njongue *et al.,* 2017; Munjeb *et al.,* 2018; Awazi *et al.,* 2019; Tsufac *et al.,* 2019; Awazi and Avana, 2019), little or nothing has been done to assess the determinants of smallholder farmers decision to take to agroforestry and choice of agroforestry systems faced with climate variability and change. It was in this light this study sought to fill this gaping knowledge void with a goal to influencing policy. The existence of a statistically significant non-causal relationship between several explanatory variables (number of farms, household size, age of household head, household income, educational level, gender, access to information, access to credit, access to land, and access to extension services) and smallholder farmers' practice of agroforestry faced with climate variability and change, demonstrates that these variables plausibly affect smallholder farmers' decision to practice agroforestry faced with climate variability and change. Meanwhile the existence of a statistically significant positive causal relationship between five explanatory variables (age of household head, access to information, household income, access to credit, and vulnerability) and smallholder farmers' practice of agroforestry faced with climate variability and change, indicates that these five explanatory variables play a major role in enhancing smallholder farmers' practice of agroforestry faced with climate variability and change. This could be attributed to the fact that age goes with experience and the older the farmer, the more experience they have about best practices like agroforestry; access to information makes farmers more knowledgeable about best practices like agroforestry and increases their propensity to practice agroforestry; more household income enables farmers to buy better farm inputs and equipments as well as pay for farm operations like clearing, tilling and pruning; access to credit gives farmers more leverage to choose best

practices like agroforestry; and vulnerability to climate variations pushes farmers to take to best practices like agroforestry that help them reduce vulnerability. Smallholder farmers' choice of agroforestry systems (agrosilvicultural, silvopastoral, and agrosilvopastoral agroforestry systems) was mainly influenced positively by access to information, household income and access to land. This could be attributed to the fact that information helps farmers to make better decisions especially with regards to the adoption and application of best farming practices. Household income enables farmers to pay for agroforestry farm operations like clearing, tilling, thinning and pruning; as well as the purchase of better farm equipments and inputs. Land on its part is an indispensable asset especially for practices like agroforestry which demand large expanses of land. Thus, smallholder farmers' practice of agroforestry and choice of agroforestry system faced with climate variability and change is influenced by several variables.

Secondly, pertaining to the contributions of agroforestry practices to the reduction of smallholder farmers' vulnerability to climate variability and change, it was found that seven agroforestry practices (home gardens with livestock, trees on cropland, live fences/hedges; trees on grazing land; coffee-based agroforestry, Taungya and improved fallows) plausibly contribute towards reducing smallholder farmers' vulnerability to climate variability and change, owing to the existence of a statistically significant negative non-causal relationship between these agroforestry practices and smallholder farmers' vulnerability to climate variability and change. Meanwhile five agroforestry practices (home garden with livestock, trees on cropland, trees on grazing land, coffee-based agroforestry, and Taungya) played a major role in reducing smallholder farmers' vulnerability to climate variability and change, owing to the existence of a statistically significant negative causal relationship between these five agroforestry practices and smallholder farmers' vulnerability to climate variability and change. The contribution of these agroforestry practices towards reducing smallholder farmers' vulnerability to climate variability and change could be attributed to the different ecosystem services provided by these agroforestry practices like food, fodder, fuelwood, finance, and soil fertility enhancement. Agroforestry as an adaptation and mitigation option to climate variability and change has been proven by different studies carried out across different parts of Africa and the tropics (Syampungani *et al.*, 2010; Rao *et al.*, 2011; Bishaw *et al.*, 2013; Mbow *et al.*, 2013; Charles *et al.*, 2013; Mbow *et al.*, 2014; Kabir *et al.*, 2015; Sobola *et al.*, 2015; Newaj *et al.*, 2016; Awazi and Tchamba, 2019), owing to its ability to supply a plethora of ecosystem services to smallholder farmers which gives agroforestry

practicing farmers an edge over their non-agroforestry practicing counterparts, faced with climate variability and change. However, little or nothing has been done so far to assess the contributions of agroforestry towards reducing smallholder farmers' vulnerability to climate variability and change in Cameroon in general and the North-West Region of Cameroon in particular which has been fully addressed by this study, thus filling the knowledge gap.

4.2.4. Smallholder farmers' agroforestry practices and resilience to climate variability and change

Here, the study sought to examine the determinants of smallholder farmers' resilience faced with climate variability and change; and the contributions of agroforestry practices to smallholder farmers' resilience to climate variability and change. Following extensive literature review, it was found that very little research had been done on these two aspects, which explains why this study sought to fill the knowledge gap. Literature review demonstrated that most of the research focusing on smallholder farmers' resilience to climate variability and change was descriptive, qualitative and conceptual (Mccarthy *et al.,* 2004; Deressa *et al.,* 2009; Gordon, 2009; Gbetibouo, 2009; Gbetibouo *et al.,* 2009; Folke *et al.,* 2010; Deressa *et al.,* 2011; World Bank, 2013; Atinkut and Mebrat, 2016). Meanhwhile very little research had been carried out to assess the contribution of agroforestry practices towards enhancing smallholder farmers' resilience to climate variability and change across different parts of Africa and the tropics (Verchot *et al.,* 2006; Rao *et al.,* 2007; Lin, 2007; Nsabimana *et al.,* 2008; Lott *et al.,* 2009; Thorlakson, 2011; Nguyen *et al.,* 2013; Bishaw *et al.,* 2013; Mbow *et al.,* 2013b; Mbow *et al.,* 2014; Vaast and Somarriba, 2014; Kumar, 2016; Liyama *et al.,* 2017; Awazi, 2018; Toppoand Raj, 2018; Awazi and Tchamba, 2019), with little or nothing done in Cameroon in general and the North-West Region of Cameroon in particular. This study therefore actively sought to fill the aforementioned knowledge gaps.

Thus, pertaining to the determinants of smallholder farmers' resilience faced with climate variability and change, it was found that a statistically significant non-causal relationship existed between explanatory variables (number of farms, household size, age of household head, household income, educational level, gender, practice of agroforestry, access to information, access to credit, access to land, and access to extension services) and smallholder farmers' resilience, which goes to show that these variables plausibly affect smallholder farmers' resilience faced with climate variability and change. Meanwhile, a statistically significant positive causal relationship was found to exist between five

explanatory variables (number of farms, access to information, household income, access to credit, and access to land) and smallholder farmers' resilience, demonstrating that these variables played a major role in enhancing smallholder farmers' resilience to climate variability and change. Hence, smallholder farmers with many farms are more resilient to climate variability and change which could be attributed to more yields obtained from these many farms which is consumed by the household and excess sold to buy farm inputs. In the same light, smallholder farmers with better access to information are more resilient than their counterparts with limited or no access which could be attributed to the fact that smallholder farmers with easy access to information are able to make plans into the future which helps them to adopt best practices. Equally, smallholder farmers with more income and access to credit facilities are more resilient than their fellow farmers with limited or no access to credit. This could be due to the fact that smallholder farmers with easy access to credit facilities are able to buy better farm inputs and can easily switch to best practices which act as a buffer to the adverse effects of climate variability and change. Meanwhile smallholder farmers with limited income and little or no access to credit facilities are unable to buy good farm inputs and cannot switch to best practices on time which renders them weak in the face of climate extremes. Similarly, smallholder farmers with more access to land were more resilient than their counterparts with limited or no land which could be attributed to the fact that land is an indispensable asset to any farmer for it is the most important fixed asset, and without it, no farming activity can take place.

As per the contribution of agroforestry practices to smallholder farmers' resilience faced with climate variability and change, it was found that seven agroforestry practices played a plausible role in affecting smallholder farmers' resilience to climate variability and change (home garden with livestock, trees on cropland, live fences/hedges, trees on grazing land, coffee-based agroforestry, Taungya and improved fallows) owing to the existence of a statistically significant non-causal relationship between these agroforestry practices and smallholder farmers' resilience to climate variability and change. Meanwhile four agroforestry practices (home garden with livestock, home garden, trees on grazing land, and coffee-based agroforestry) played a major role in enhancing smallholder farmers' vulnerability to climate variability and change, owing to the existence of a statistically significant positive causal relationship between these agroforestry practices and smallholder farmers' resilience to climate variability and change. Thus, it was noticed that most of the agroforestry practices have a positive causal relationship with smallholder farmers' resilience

to climate variability and change. This shows that as agroforestry practices increase, smallholder farmers' resilience to climate variability and change also increases. This improvement in smallholder farmers' resilience to climate variability and change following an increase in agroforestry practices could be attributed to the environmentally benign, low cost and sustainable nature of agroforestry practices when compared to other practices (especially monoculture) taken up by some smallholder farmers.

CHAPTER FIVE

CONCLUSION, RECOMMENDATIONS AND POLICY IMPLICATIONS

5.1. Conclusion

This study sought to attain four specific objectives: assess the drivers of smallholder farmers' vulnerability to climate variability and change in the North-West Region of Cameroon; characterize smallholder farmers' agroforestry practices in the face of climate variability and change in the North-West Region of Cameroon; examine the contribution of agroforestry practices to the reduction of smallholder farmers' vulnerability to climate variability and change; and evaluate the role of agroforestry practices to the enhancement of smallholder farmers' resilience faced with the impacts of climate variability and change. Based on the findings of this study, it could be safely said that all these four specific objectives were holistically attained.

Pertaining to the drivers of smallholder farmers' vulnerability to climate variability and change, it was found that temperature is on the rise while rainfall is scanty and erratic. This was vindicated by smallholder farmers' perceptions and analysis of over five decades of climate data for the study area. There was almost general unanimity amongst smallholder farmers that recurrent extreme weather events and poverty were the main drivers of vulnerability to climate variability and change, and most smallholder farmers rated that they were highly vulnerable to the adverse effects of climate variability and change. A significant negative causal relationship was found to exist between smallholder farmers' vulnerability to climate variability and change, and five explanatory variables (household size, age of household head, access to information, household income and access to land) which goes to show that these explanatory variables contribute enormously towards reducing smallholder farmers' vulnerability to climate variability and change.

With regards to the characterization of smallholder farmers' agroforestry practices in the face of climate variability and change, it was found that home garden with livestock, trees on croplands and home gardens were the most widespread agroforestry practices of smallholder farmers. A categorization of smallholder farmers' agroforestry practices revealed that agroforestry practices categorized under the agrosilvicultural agroforestry system were the most dominant, with six agroforestry practices. The most recurrent agroforestry products and

services identified by farmers were food and fuelwood; the main classes of agroforestry tree/shrub species integrated on smallholder farmers' agroforestry plots were fruit trees and fuelwood trees/shrubs; the most common food crops integrated on smallholder farmers' agroforestry plots were maize (Zea mays), Cassava (*Manihot esculenta*), and cocoyams (*Colocasia spp*); while the commonest livestock species reared by smallholder farmers practicing agroforestry were the indigenous fowl (*Gallus gallus domesticus*), the domestic pig (*Sus domesticus*), and the domestic goat (*Capra aegagrus hircus*); meanwhile the most commonly integrated tree/shrub species on smallholder farmers' agroforestry plots were avocado (*Persea american*), guava (*Psidium guajava*), bitter leaf (*Vernonia amygdalina*), African plum (*Dacryodes edulis*), Mango (*Mangifera indica*), Cola (*Cola anomala*) and Eucalyptus (*Eucalyptus spp*). All these go to show that smallholder farmers' agroforestry practices in the North-West Region of Cameroon are diverse which accounts for the diverse products and services obtained from these different agroforestry practices.

With respect to the contribution of agroforestry practices to the reduction of smallholder farmers' vulnerability faced with climate variability and change, it was found that eight (08) agroforestry practices had a negative causal relationship with smallholder farmers' vulnerability to climate variability and change. Of the eight agroforestry practices, five (05) had a significant or strong negative causal relationship with smallholder farmers' vulnerability to climate variability and change. These five agroforestry practices having a strong negative causal relationship with smallholder farmers' vulnerability to climate variability and change were the home garden with livestock, trees on croplands, trees on grazing lands, coffee-based agroforestry and Taungya. It can therefore be said that the aforementioned five agroforestry practices have a high propensity to reduce smallholder farmers' vulnerability to climate variability and change.

As per the agroforestry practices enhancing smallholder farmers' resilience to climate variability and change, it was found that seven (07) agroforestry practices namely home gardens with livestock, trees on croplands, trees on grazing lands, live fences/hedges, coffee-based agroforestry, Taungya and improved fallows, had a significant non-causal relationship with smallholder farmers' resilience to climate variability and change (X^2 >34, p<0.01). Of the afore-cited seven (07) agroforestry practices, four (04) practices namely home gardens with livestock, home gardens, trees on grazing lands and coffee-based agroforestry had a significant positive causal relationship with smallholder farmers' resilience to climate variability and change. This proves beyond reasonable doubt that the practice of these four

agroforestry practices played a significant role in enhancing smallholder farmers' resilience to climate variability and change.

To sum up, smallholder farmers in Mezam division, the North-West Region of Cameroon are highly vulnerable to the adverse effects of climate variability and change; and the practice of agroforestry plays a major role towards reducing vulnerability and enhancing resilience of to climate variability and change. Thus, the practice of agroforestry by smallholder farmers contributes towards the attainment of some of the Susustainable Development Goals (SDGs) especially goal 1on poverty reduction; goal 2 on zero hunger; and goal 13 on climate action.

5.2. Recommendations

Drawing inspiration from the findings of this study, which clearly showed that agroforestry practices contribute towards reducing vulnerability and enhancing smallholder farmers' resilience faced with climate variability and change, the following recommendations to smallholder farmers, local authorities, and the government were doled out:

5.2.1. To smallholder farmers

- ✓ Alter planting dates in order to cope with fluctuations in planting seasons caused by climate variability and change;
- ✓ Take to more off-farm activities in order to reduce dependence on agriculture which is very climate dependent;
- ✓ Switch from purely rain-fed agriculture to other systems involving irrigation in order to reduce the impacts of prolong dryness on farm crops, caused by erratic rainfall;
- ✓ Try to reconcile local knowledge about past weather conditions to the present dispensation in order to avoid being caught off-guard by sudden extreme weather events;
- ✓ Attend training workshops and seminars treating issues of climate variability and change in order to acquire vital information, build capacity and broaden their scope as far as the thorny issue of climate variability and change is concerned;
- ✓ Intensify their existing agroforestry practices and adopt new agroforestry technologies in order to build their resilience to climate variability and change;
- ✓ Provisioning services obtained from agroforestry systems should not only be used for subsistence, but some should be sold in order to raise income which could go a long way to enhance resilience to climate variability and change;

- ✓ More fruit, fuelwood and building material trees should be integrated within agroforestry farm plots in order to obtain diverse products which could enhance resilience to climate variability and change;
- ✓ More diverse crop and livestock species should be integrated within agroforestry systems in order to reduce the adverse effects of climate variability and change on the system;
- ✓ Take to easily managed agroforestry systems which will help to reduce costs thereby enhancing their resilience to climate variability and change.

5.2.2. To local authorities

- ✓ Organize training workshops and seminars on climate variability and change in order to school farmers on the impacts of climate variability and change as well as best practices such as agroforestry which could help them reduce the impacts of climate variability and change;
- ✓ Ease access to land especially for women in order to enable them practice agroforestry which would help enhance their resilience to climate variability and change;
- ✓ Create jobs in non-farming sectors which will encourage farmers to take part in off-farm activities which will go a long way to diversify their income and enhance their resilience to climate variability and change;
- ✓ Encourage farmers' involvement in community organizations like farming groups which will help them get novel ideas through information and knowledge sharing;
- ✓ Construct and maintain farm-to-market roads to ease evacuation of farm produce to the market which will go a long way to increase farmers' income and enhance resilience to climate variability and change;
- ✓ Create more local markets to ease the marketing of farmers' produce which help to increase farmers' income, thus enhancing resilience to climate variability and change.

5.2.3. To the government

- ✓ Create and staff more research institutions involved in climate change research and weather forecast, in order to provide farmers with much needed weather information;
- ✓ Create and staff more research institutions involved in agroforestry research in order to provide smallholder farmers with climate-smart agroforestry practices;

- ✓ Construct more farm-to-market roads in order to ease farmers' evacuation of their farm produce to the market;
- ✓ Create a stabilization fund that helps to stabilize fluctuations in the prices of farm products;
- ✓ Create more markets to ease the sale of farmers' produce;
- ✓ Employ and deploy more agricultural extension agents to assist smallholder farmers on the field;
- ✓ Create more jobs in the secondary and tertiary sectors in order to reduce dependence on farming activities which are too climate dependent;
- ✓ The land tenure system should be reoriented in order to ease access to land especially for women;
- ✓ Tree rights should be guaranteed for practitioners of agroforestry in order to encourage farmers to take up the practice;
- ✓ Farmers' banks should be created to provide credit and loans to smallholder farmers;
- ✓ The existing agroforestry practices of smallholder farmers should be promoted and more climate-smart agroforestry technologies should be invented and vulgarized among smallholder farmers to reduce their vulnerability and enhance their resilience to climate variability and change.

5.3. Policy implications

This study sought to assess the contributions of agroforestry practices to the reduction of vulnerability and the enhancement of resilience in smallholder farming systems faced with climate variability and change. Based on the findings of the study, the following policy implications arise:

First and foremost, three main agroforestry systems (agrosilvicultural, silvopastoral and agrosilvopastoral agroforestry systems) were practiced by smallholder farmers faced with climate variability and change. Thus, policies geared towards encouraging the practice of agroforestry in smallholder farming systems faced with climate variability and change should lay emphasis on these three main agroforestry systems.

Secondly, the main agroforestry practices that played a significant contribution towards reducing smallholder farmers' vulnerability to climate variability and change were home garden with livestock, trees on croplands, trees on grazing lands, coffee-based agroforestry,

and Taungya. Therefore, policies geared towards attenuating smallholder farmers' vulnerability to climate variability and change should focus on these five main agroforestry practices.

Last but not the least, the main agroforestry practices that played a major role towards enhancing smallholder farmers' resilience to climate variability and change were home garden with livestock, home garden, trees on grazing lands, and coffee-based agroforestry. Hence, policies geared towards using agroforestry to enhance smallholder farmers' resilience to climate variability and change should take a keen look at these four agroforestry practices, and adequate measures should be taken to promote them.

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APPENDICES

Appendix 1: List of key informants interviewed in Mezam Division, North-West Region of Cameroon

SN	Name	Portfolio
1	Anonymous	Regional Delegate of Agriculture and Rural Development
2	Anonymous	Regional Chief of Service for agricultural statistics
3	Anonymous	Regional chief of service for phytosanitary and pest control
4	Anonymous	Regional chief of service for crop production
5	Anonymous	Divisional Delegate of agriculture and rural development
6	Anonymous	Sub-divisional delegate of agriculture and rural development for Santa
7	Anonymous	Sub-divisional delegate of agriculture and rural development for Tubah
8	Anonymous	Sub-divisional delegate of agriculture and rural development for Bafut
9	Anonymous	Sub-divisional delegate of agriculture and rural development for Bamenda I
10	Anonymous	Sub-divisional delegate of agriculture and rural development for Bamenda II
11	Anonymous	Sub-divisional delegate of agriculture and rural development for Bamenda III
12	Anonymous	Chief of agricultural post for Awing
13	Anonymous	Chief of agricultural post for Mbei Santa
14	Anonymous	Chief of agricultural post for Akum
15	Anonymous	Chief of agricultural post for Bambui
16	Anonymous	Chief of agricultural post for Bambili
17	Anonymous	Chief of agricultural post for Kedjom-Keku
18	Anonymous	Chief of agricultural post Mendakwe
19	Anonymous	Chief of agricultural post Nkwen village
20	Anonymous	Chief of agricultural post Alabukam – Mankon
21	Anonymous	Regional delegate of environment, protection of nature and sustainable development
22	Anonymous	Regional chief of service for sustainable development
23	Anonymous	Regional chief of service for environmental protection
24	Anonymous	Divisional delegate of environment, protection of nature and sustainable development
25	Anonymous	Regional delegate of forestry and wildlife
26	Anonymous	Regional chief of service for forestry
27	Anonymous	Regional chief of service for wildlife
28	Anonymous	Regional chief of service for forestry statistics
29	Anonymous	Divisional delegate of forestry and wildlife
30	Anonymous	Regional coordinator of ANAFOR

Appendix 2: Average monthly temperature 1961 – 2018 for Mezam Division, North-West Region of Cameroon

Years/ Months	1961 - 1965	1966 - 1970	1971 - 1975	1976 – 1980	1981 - 1985	1986 - 1990	1991 - 1995	1996 - 2000	2001 - 2005	2006 - 2010	2011 - 2015	2016 - 2018
Jan	20.4	19.9	20.1	19.9	18	20.2	20.3	19.8	18.2	21	20.6	21.1
Feb	20.7	21.5	21.1	20.6	18.1	21.3	20.2	23.2	18.1	22.1	21.2	22.3
Mar	20.5	20.8	20.8	20.9	19.1	21.7	21.3	21.4	18.4	21.5	21.4	20.6
Apr	20.3	20.4	20.4	20.8	20	20.6	21	20.8	18.5	21	20.9	19.9
May	20.2	20.1	20.3	20.2	20	20.6	20.6	20.3	18.4	20.1	20.3	21.4
June	21.4	19.9	20.1	19.9	18	20.2	20.1	19.8	18.2	21	20.6	21.1
July	19	17.9	18.2	18	17.8	18	18.4	18.7	19.1	19.5	19.8	21.5
Aug	19.7	17.8	18.1	18.1	18.1	18.3	18.5	17.6	18.2	18.6	19.7	19.2
Sept	18.2	18.1	18.4	18.5	18.4	18.9	19.1	18.2	18.6	19.2	19.5	20.4
Oct	19.8	19.7	19.5	19.4	18.3	20.2	19.7	18.9	19.2	17.6	20.7	21.3
Nov	19.1	19.3	19.3	19.6	19.3	20.5	20	19.2	19.1	21.2	19.9	20.5
Dec	21.2	19.5	19.5	19.6	19.4	16.4	20.5	19.3	19.7	20.5	20.6	21.3
Avr.	**20.02**	**19.82**	**19.68**	**19.62**	**18.52**	**20.02**	**20.20**	**20.50**	**18.56**	**20.16**	**20.50**	**21**

Source: Regional service of meteorology for the North-West Region of Cameroon

Appendix 3: Average monthly rainfall 1961 – 2018 for Mezam Division, North-West Region of Cameroon

Years/ Months	1961 - 1965	1966 - 1970	1971 - 1975	1976 – 1980	1981 - 1985	1986 - 1990	1991 - 1995	1996 - 2000	2001 - 2005	2006 - 2010	2011 - 2015	2016 - 2018
Jan	0	21.2	4.4	11.3	24.7	13	17.1	16.4	4	4.6	0.8	0
Feb	65.2	28.9	51.6	68.6	13.6	20.2	22.4	18.4	14.1	16.4	28.2	12.7
Mar	152.7	192.2	147.7	102.7	174.4	84.6	110.7	127.4	90.9	85.8	71.3	47.4
Apr	234.1	214.5	150.7	209.2	171.5	166.4	202.5	141.8	95.5	213.5	201.4	147.2
May	183.4	191.8	145.1	178.5	134.6	159.5	209.6	177.2	194.4	164.9	253.1	178.4
June	335.5	315.7	242.4	279.3	249.7	262.9	259.2	171.2	351.9	303.8	298.2	258.9
July	463.7	457.7	361.6	481.7	410.8	391.3	166.4	397.3	407.2	410.8	350.1	342.7
Aug	358.1	445.6	342.1	406.7	517.9	453.9	408.3	409.4	425	449.1	354.2	279.5
Sept	406.1	554.6	420.6	432.2	425	417	358.7	391.7	411.9	380.1	302.5	300.4
Oct	280.2	218.6	210.9	281.3	293.6	224.3	236.1	324.5	202.5	227.1	260.4	203.4
Nov	72	166.6	43.4	4.5	31.5	18.9	32.7	66.2	51	58.8	69.5	36.8
Dec	34.9	1.4	9.3	0.1	13.4	17.9	1.2	5.4	18.4	22.4	19.6	2.3
Total	**2585.9**	**2808.8**	**2129.8**	**2456.1**	**2460.7**	**2229.9**	**2024.9**	**2246.9**	**2266.8**	**2337.3**	**2209.3**	**1809.7**

Source: Regional service of meteorology for the North-West Region of Cameroon

Appendix 4: Average monthly rainy days 1961 – 2018 for Mezam Division, North-West Region of Cameroon

Years / Months	1961 to 1965	1966 to 1970	1971 to 1975	1976 to 1980	1981 to 1985	1986 to 1990	1991 to 1995	1996 to 2000	2001 to 2005	2006 to 2010	2011 to 2015	2016 to 2018
Jan	0	2	1	2	2	1	1	2	1	1	1	0
Feb	7	4	3	7	2	2	2	3	3	3	4	3
Mar	14	16	14	12	13	10	12	10	11	10	8	9
Apr	19	21	19	21	20	16	20	19	20	19	16	15
May	12	21	20	22	19	21	22	19	22	20	19	18
June	26	25	24	26	25	23	23	23	24	24	21	20
July	29	29	26	28	28	27	28	28	28	27	26	24
Aug	25	27	25	30	30	28	28	25	26	27	25	24
Sept	27	26	29	28	28	27	25	28	25	28	25	23
Oct	25	26	23	24	23	22	25	25	24	24	20	19
Nov	5	8	6	2	7	5	6	20	13	6	5	3
Dec	3	1	1	1	1	2	1	2	1	1	2	0
Total	**192**	**206**	**191**	**203**	**198**	**184**	**193**	**204**	**198**	**190**	**172**	**158**

Source: Region service of meteorology for the North-West Region of Cameroon

Appendix 5: Questionnaire addressed to smallholder farmers in Mezam Division, North-West Region of Cameroon

Division_____

Sub-Division_____
Name of village_____
Location_____
Questionnaire number_____
Interviewer_____
Date_____

I. Identification and General information

1. Name of household head_____
2. Gender: Male ☐ Female ☐ Age_____ Marital status: Married ☐ Single ☐ Widow/Widower ☐ Divorced ☐
3. How many of you live in this household?
4. What is your level of education? None ☐ Primary ☐ Secondary ☐ Tertiary ☐
5. What is your farm size?
6. How many years of farming experience do you have?
7. Are you a member of any farming group? Yes ☐ No ☐
8. What is your annual family income?

II. Survey pertaining to smallholder farmers' perception of variations and changes in climate parameters and drivers of vulnerability to climate variability and change

II.1. Smallholder farmers' perception of variations and changes in climate parameters

1. Have you experienced extreme weather or climate events in recent years? **Yes** ☐ **No** ☐
2. If yes, which extreme weather event(s) did you experience?_____
_____
3. How severe was it?_____
4. Did you have access to early warning before the occurrence of extreme weather and climate events? **Yes** ☐ **No** ☐
If yes, what did you do with the information in preparation for the extreme weather or climate event?_____
5. Can you remember some of the extreme weather/climate events you experienced in the past years?

Year	Event	Degree of severity

Use the severity scale below:
(a) Very severe ☐ **(b) Moderately severe** ☐ **(c) Less severe** ☐ (d) **Not severe** ☐
6. If forecast about a coming rainy season could be provided reliably, how many weeks or months in advance of the season would you need to receive the information for it to be useful to you?
(a) Two weeks ☐ **(b) Three weeks** ☐ **(c) A Month** ☐ **(d) Two months** ☐
(e) others? Specify
7. List and rank your sources of climate information_____
_____
8. In your opinion which of them are very reliable? Give reasons_____
9. How frequently do you receive climate information from these sources?_____
10. Compare variation in rainfall, temperature, wind speed, and sunshine in the following time scales:

Climate parameter	Year to year	< 5 years ago	5-10 years ago	11-14 years ago	15-19 years ago	20-24 years ago	25-29 years ago	> 30 years ago
Rainfall								
Temperature								
Wind								
Sunshine								

Use the scale below:
(a) Very high (b) High (c) Average (d) Low (e) Very low
11. If forecasts about a coming rainy season could be provided reliably, what type of forecast information will be most useful to you?

- ✓ Forecasts about when the rains are expected to start falling in your area ☐
- ✓ Forecasts about when the rains are expected to end in your area ☐
- ✓ Forecasts about whether the amount of rain falling will be above average, normal or below average ☐

✓ Forecasts about the distribution of rainfall during the season ☐

Use the usefulness scale below:

(a) Very useful ☐ **(b) Moderately useful** ☐ **(c) Less useful** ☐ **(d) Not Useful** ☐

12. How do you feel the following climate parameters have varied/changed in the recent past?

- **The total amount of rainfall:**

Time period	Increased a lot	Increased	Stayed the same	Decreased	Decreased a lot

- **Temperature:**

Time period	Much hotter	Hotter	Stayed the same	Cooler	Much cooler

- **Rainfall consistency:**

Time period	Much more variable	More variable	Stayed the same	Less variable	Much less variable

- **Total amount of sunshine:**

Time period	Increased a lot	Increased	Stayed the same	Decreased	Decreased a lot

- **Incidence of violent winds and thunder storms:**

Time period	Increased a lot	Increased	Stayed the same	Decreased	Decreased a lot

II.2. Smallholder farmers' perception of drivers of vulnerability to climate variability and change

1. Have you personally been affected by recurrent extreme weather events? **Yes** ☐ **No** ☐
2. If yes, was/were the impact(s) positive or negative? **Positive** ☐ **Negative** ☐
3. If the impact(s) was/were positive, can you cite it/them?_____

_____
_____
4. If the impact(s) was/were negative, can you cite it/them?_____
_____
_____
5. Which factors do you think contribute to make you vulnerable to extreme weather events?
_____
_____
_____
6. Are there some factors that you think contribute more to increase your vulnerability? **Yes** ☐ **No** ☐
7. If yes, can you name them?_____
_____
_____
8. Provide suggestions that will reduce your vulnerability to extreme weather events_____
_____
_____
_____

III. Survey pertaining to smallholder farmers' agroforestry practices

1. Do you practice agroforestry? **Yes** ☐ **No** ☐
If No, why?_____
_____
_____
If Yes, which agroforestry practices do you practice?_____
_____
_____
2. What are some of the tree/shrub species you integrate on your agroforestry farm plots?__
_____
_____
3. What are some of the crop species you integrate on your agroforestry farm plots?_____
_____
_____
4. What are some of the animal species you raise?_____
_____
_____
5. Do you derive benefits from your agroforestry practices? **Yes** ☐ **No** ☐
If Yes, cite the benefits you derive from your agroforestry practices_____
_____
_____

IV. Survey pertaining to the contribution of agroforestry practices to the attenuation of smallholder farmers' vulnerability to climate variability and change

1. Do you think agroforestry practices contribute towards reducing your vulnerability faced with climate variability and change? **Yes** ☐ **No** ☐
If No, why?_____
_____
_____
If Yes, how do you think agroforestry practices contribute to reduce your vulnerability to climate variability and change?_____
_____
_____
2. Which agroforestry practices do you think contribute the most towards reducing your vulnerability to climate variability and change?_____
_____
_____
3. What do you think can be done to increase the contribution of these agroforestry practices towards reducing smallholder farmers' vulnerability to climate variability and change?
_____
_____

V. Survey pertaining to the contribution of agroforestry practices to enhancement of smallholder farmers' resilience to climate variability and change

1. Do you think agroforestry practices contribute towards enhancing your resilience in the face of climate variability and change? **Yes** ☐ **No** ☐
If No, why?_____
_____
_____
If Yes, how do you think agroforestry practices contribute to enhance your resilience to climate variability and change?_____
_____
_____
2. Which agroforestry practices do you think contribute the most towards enhancing your resilience to climate variability and change?_____
_____
_____
3. What do you think can be done to increase the contribution of these agroforestry practices towards enhancing smallholder farmers' resilience to climate variability and change?
_____
_____
_____

Appendix 6: Interview guide addressed to Key Informants in Mezam Division, North-West Region of Cameroon

Name of Key Informant_____
Gender of Key Informant_____
Position Occupied_____
Interview guide number_____
Interviewer_____
Date_____

1. Have you noticed variations and/or changes in climate in your area?_____
2. If affirmative, what makes you think that variations and/or changes in climate is/are a reality **OR** what in your opinion are the indicators of variations and changes in climate?_____
_____
3. What in your opinion are the main effects of increasing variation of these climate elements on smallholder farmers?_____
_____
4. In your opinion, are smallholder farmers vulnerable to the effects of increasing variation and/or changes in climate elements? **Yes** ☐ **No** ☐
5. If yes, why then do you think they are vulnerable?
_____
_____

6. Are smallholder farmers taking any measures to reduce vulnerability and beef-up their resilience to extreme climate and weather events? **Yes** ☐ **No** ☐
7. If yes, which measures are they taking?
_____
_____
_____
8. How do you judge the effectiveness of these measures? Give reasons for your answer
_____
_____
9. What do you think determines the choice of the measures or options smallholder farmers decide to adopt in the face of climate variability and change?
_____
_____
10. Have you proposed any measures or options to smallholder farmers which can help them to become more resilient? **Yes** ☐ **No** ☐
11. If yes, which measures have you proposed or recommended to the farmers?

_____

_____

12. What are the farmers' opinions about the proposed measures?

_____

13. Do smallholder farmers practice agroforestry in your area?_____

14. If affirmative, what are the different agroforestry practices taken up by farmers?_____

_____

_____

15. In your opinion what is the role of agroforestry in helping smallholder farmers adapt to and/or mitigate the effects of climate variability and/or change?_____

_____

_____

16. Have you been encouraging smallholder farmers to practice agroforestry? **Yes** ☐ **No** ☐

17. If affirmative, why do you think some smallholder farmers are still hesitant when it come to practicing agroforestry?_____

_____

_____

18. What do you think can be done to encourage smallholder farmers to practice agroforestry, especially in the face of climate variation and change?_____

_____

_____

19. How can you rate your level of knowledge on climate variability and change?

_____

_____

20. Was "Climate Change" taught as a course during your schooling days? **Yes** ☐ **No** ☐

21. Is there a service in your ministry responsible for issues on climate variability and change? **Yes** ☐ **No** ☐

22. Have you received any training to handle problems associated with climate variability and change? **Yes** ☐ **No** ☐

23. If yes, how many training sessions have you undertaken?

_____

Provide the themes of the training_____

_____

24. How will you rate exchange of experience between colleagues on climate variability and change?_____

25. How will you rate communication of information on climate variability and change between agricultural officers and smallholder farmers?_____

26. In your opinion, can the effects resulting from the inter-annual variation in climate elements be controlled? **Yes** ☐ **No** ☐

27. If yes, how can this be achieved?_____

_____

28. If no, which reasons can you advance?_____

_____

Thank You Very Much for Your Time

Appendix 7: Data collection sheet for tree/shrub inventories on smallholder farmers'agroforestry plots

Agroforestry plot number	Type of agroforestry practice	Geographical coordinates of plot	Sub-division	Local name of species	Botanical name of species	Family of species

Appendix 8: Focus group discussions

Photo 1a: Focus group discussion

Photo 1b: Focus group discussion

Photo 1c: Focus group discussion

Photo 1d: Focus group discussion

Appendix 9: Household surveys

Photo 1a: Household survey

Photo 1b: Household survey

Appendix 10: Inventory on agroforestry plots

Photo 1a: Trees on cropland

Photo 1b: Trees on cropland

Photo 1c: Trees on cropland

Photo 1d: Trees on cropland

Photo 1e: Trees on cropland

Photo 1f: Trees on cropland

Photo 2a: Improved fallow

Photo 2b: Improved fallow

Photo 3a: Silvopastoral practice

Photo 3b: Silvopastoral

Photo 4a: Live fence/hedge

Photo 4b: Live fence/hedge

Photo 5a: Homegarden

Photo 5b: Homegarden

Photo 6a: Taungya

Photo 6b: Taungya

Appendix 11: Inventory on non-agroforestry farm plots

Photo 1a: Tomato monocrop

Photo 1b: Huckleberry monocrop

Photo 1c: Groundnut monocrop

Photo 1d: Cassava monocrop

Photo 2a: Mixed cropping

Photo 2b: Mixed cropping

Photo 2c: Mixed cropping

Photo 2d: Mixed cropping