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Climate Variability and Change in the Bamenda Highlands of North Western Cameroon: Perceptions, Impacts and Coping Mechanisms

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Authors' contributions

This work was carried out in collaboration between all authors. Author NMI designed the study, carried out field investigations and data collection, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Authors BRA and DB assisted in the analyses of the study, literature searches and proofreading of the manuscript. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The study investigates how local people perceive climate change/variability, its impacts and coping mechanisms in the Bamenda highlands of north western Cameroon.
Study Design: A household-based descriptive cross-sectional study.
Place and Duration of Study: The Bamenda highlands of North West western Cameroon for the farming season 2012–2013 between June 2009 and July 2010.
Methodology: A "bottom-up" approach, which seeks to gain insights from the farmers themselves based on a farm household survey was employed. Meteorological data for the region was compared with local views gathered through focus group discussions and interviews in 12 villages selected from four of the seven divisions that make up the region. Household interviews explored

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the local significance of seasonality, climate variability, and climate change.
Results: Rainfall is characterized by significant interannual variability, with the last ten years characterized by undefined periods of dryness and wetness. Reduced rainfall and water supply, upward shifting of certain plant species and increased incidence of diseases on crops are major issues commonly raised by respondents. Changing the planting dates 130 (15.8%), traditional moisture holding practices, 200(22.2%) and the adoption of mixed cropping, 172 (19.1%) are some of the local coping mechanisms currently adopted by farmers. Lack of knowledge concerning appropriate adaptations (37±18.5), and lack of information about climate change (29±14.5) were among the barriers to adaptation. On the demographic and socioeconomic characteristics, famers "with" and "without" barrier to climate change adaptation strategies differed significantly on most of the independent variables ($p<.001$).
Conclusion: The study highlights the need for adaptation to current land, forest and water management practices to maintain livelihoods in the face of changes many people are not expecting.

Keywords: Bamenda highlands; bottom-up approach; perception; coping mechanisms; climate change and variability; Cameroon.

1. INTRODUCTION

Since the industrial revolution, our energy use has grown and this has resulted in more and more fossil fuels being burnt, releasng greenhouse gases into the atmosphere. According to the World Metrological Organization [1], greenhouse gas radiative forcing (expressed in Watts per square meter), the difference of insolation absorbed by the Earth and energy radiated back to space, has registered an increase of 34% since 1990, the baseline year for the Kyoto Protocol. At the current rate, global temperatures are expected to increase in the range 1.4 - 5.8℃ by 2100 and will lead to more volatile weather patterns that may go into the mix to destabilize the world a bit more [2].

The impacts of climate change are apparent historically, currently important, and will continue to be important in both the short and long term. With increases of 1.5℃ to 2.5℃, approximately 20 to 30% of plant and animal species are expected to be at risk of extinction [3] with severe consequences for food security in developing countries. By 2020 yields from rain fed agriculture are likely to decline by 50% in some African countries [4]. Freshwater availability is likely to change in several regions impacting freshwater biodiversity; hydrological services and agricultural productivity putting at risk both ecosystems and people. According to [5], agriculture, forestry, and fisheries are highly sensitive to climate change and climate change is very likely to have a serious impact on their productive functions. Climate change and variability present new development challenges, particularly in Sub-Saharan African countries where the majority of the population depends on climate-sensitive activities, in particular, agricultural production [6].

Several adaptation strategies and coping mechanisms have been initiated with the goal of recovering the structure and function of tropical ecosystems from the adverse effects of climate change. Most authors focus on perceptions of climate and deal with temperature and rainfall, i.e., amount, annual distribution, start and end dates and meteorological data are often used to confirm peoples' assessments [7] or refute them [8] for long-term perceptions. Other studies have dealt with perceptions of seasonality [9], perceptions of risks and threats related to climate variability [10] and local knowledge in forecasting weather and adapting to climate [11]. The adopter perceptions paradigm posits that the adoption process starts with the adopters' perception of the problem and technology proposed [12]. This paradigm argues that perceptions of adopters are important in influencing adoption decisions [13]. However, perceptions are context and location specific due to heterogeneity in factors that influence them such as culture, education, gender, age, resource endowments and institutional factors [14].

Since the emergence of climate change at the top of the political agenda, a growing number of research and guidance tools and methods are available for policymakers under climatic uncertainty, including principles and steps for robust decision making under uncertainty [15], principles for avoiding maladaptation [16], and characteristics of sustainable adaptation [17]. The guidance tools and methods range from adjustments in existing practices to more fundamental changes in development practices. The former present a traditional linear view of the policymaking process, while the latter challenges equilibrium, predictability and linear thinking and management practices while also proposing diversity, dynamism and uncertainty to be embraced at the core of policy-making. However, experience has shown that identified adaptation measures do not necessarily translate into changes, because adaptation strategies to climate change and physiological barriers to adaptation are local specific [18]. Thus a better understanding of the local dimensions of climate change is essential to develop appropriate adaptation measures that will mitigate adverse consequences of climatic change impact.

When considering climate change, indigenous peoples and marginalized populations warrant particular attention. Impacts on their territories and communities are anticipated to be both early and severe due to their location in vulnerable environments, including small islands, high altitude zones, desert margins and the circumpolar Arctic. Indeed, climate change poses a direct threat to many indigenous and marginalized societies due to their continuing reliance upon resource-based livelihoods. There is a need to understand the specific vulnerabilities and adaptation capacities of indigenous and marginalized communities. Studies have demonstrated the value of indigenous peoples' observations of changes in climate-related weather patterns (e.g.,[19]). Their knowledge of past ecological patterns can help reconstruct historical baselines [20]. Traditional ecological knowledge of ecosystem health and species distributions can contribute to culturally appropriate adaptation [21].

This paper provides important information on local farmer's perception of climate change, local adaptation/coping mechanisms currently employed, and barriers to adaptation by exploring specific examples from recent research in the Bamenda highlands of Cameroon, with the aim of providing policy makers insights into this important socioeconomic issue. The study is particularly concerned with how these variations may have caused problems or hardships, what the responses and constraints have been, and what can be learned from these that may assist in future adaptation. Specifically, the paper aims to:

1. Examine farmers' perceptions of climate change and variability and the different levels of climate change risks using household survey;
2. Explore the adaptation strategies and coping mechanisms farmers have already adopted to cope with the consequences of climate change.
3. Identify barriers to climate change adaptation and the associations between these barriers with coping mechanisms; and
4. Recommend plausible policy interventions that match farmers, perceptions, experiences, adaptation strategies and coping mechanisms in the region.

Coping responses or mechanisms are unplanned, reactive, and short-term responses to immediate threats, whereas adaptive strategies refer to proactive and anticipatory changes over long periods to reduce the impacts of recurrent threats or gradual changes [22].

2. MATERIALS AND METHODS

2.1 Study Area

This study was carried out in the Bamenda highlands (17,300 km^2 (6,680 sq mi)) of North West western Cameroon located between latitudes 5°40' and 7° to the North of the equator, and between longitudes 9°45 and 11°10' to the East of the Meridian. It is bordered to the south-west by the South-West region, to the south by West Region, to the east by Adamawa Region, and to the north by the Federal Republic of Nigeria (Fig. 1).

As per the 2005 population census, the region counts 1,728,953 people with a density of 100 /km^2. Although these divisions are separated from each other by less than 200 km, differences in elevation and wind exposure account for differences in local climates, for example, temperature and orographic precipitation.

The region is characterized by accidental relief of massifs and mountains. It features several dormant volcanoes, including the Mount Oku of all. A cool temperate-like climate, influenced mainly by mountainous terrain and rugged topography also characterized the region. Average rainfall is about 2400 mm, temperature average 23°C, ranging between 15°-32°C [23]. There are two main seasons; the rainy season which starts from April and ends in October, and dry season from November to February. The dry

Fig. 1. Location of study area with sampling points (in grey)
(Source: Adapted from http://en.wikipedia.org)

season is characterized by the Harmattan with dry air. Forests once largely covered the Bamenda Highlands region of Cameroon. However, the forests were progressively cleared for farmland and grazing, and today, only patches remain. Although small, these patches are recognized as globally important sites for conservation of biological diversity. According to the 2005 population census result, the population of region was about 1.75 million.

2.2 Design

This was a household-based descriptive cross-sectional study. A "bottom-up" approach, which seeks to gain insights from the farmers themselves based on a farm household survey, was employed. Farm-level data were collected from 200 households for the farming season 2012–2013. A multi-stage sampling technique was used to select respondents for the study. In stage one, four divisions were selected by a simple random sampling technique utilizing a ballot method. In the second stage, two rural/peri-urban villages were chosen by a simple random sampling technique from each of the divisions. In stage three, for each village chosen, streets were selected using a systematic sampling method. In stage four, for each street selected houses were selected using a systematic random sampling method. In stage five, purposive snowball sampling [24] was used to select the sample units (farmers). The participants were purposively selected in order to gain insights from a cross-section of the village with respect to experiences and knowledge related to the study over the past three decades. Hence, the sample consisted only farmers aged 30 or more years made up of men and women with varying livelihood opportunities.

2.3 Data Collection

Secondary data were collected on climate attributes from a review of literature on climate change. The literature review included various published and unpublished sources on traditional knowledge and climate change [e.g. [25-26], research papers [e.g. [27] and other written materials. This led to the compilation of a database that identified and described a broad set of institutions working on climate change and adaptation strategies in the region. Two distinct domestic climate-change related data sources were explored: Farmer's survey and Institutional survey.

Primary data collection used both qualitative and quantitative approaches. The qualitative methods of data collection used include Participatory Rural Appraisal (PRA) techniques such as historical trend analysis and Focus Group Discussions (FGDs). A checklist of topics for semi-structured interviews and focus group discussions was established (Table 1).

Table 1. Checklist of topics for semi-structured interviews and focus group discussions

Key theme	Variables investigated
Background information of respondent	- Educational level - Income level - Household size - Rainfall and temperature variability - Timelines and trend lines
Current exposure sensitivities	**Climatic risks/ hazards**: - Temperature changes - Precipitation changes - Droughts - Perception(s) towards major climatic hazards - Biophysical/Social/Economic - Water and climate - Historical data(when and how exposed)
Current adaptive/response strategies	**Present adaptive practices/ responses:** - Formal and Local response mechanisms - How exposures are managed - What constrains adaptive strategies

The quantitative method used is a household questionnaire survey. Questions in the survey included changes in weather patterns over a ten-year period in relation to agriculture and what might have caused these changes. General household characteristics were also captured in this survey. Perception questions were asked from the respondents to know the level of their perceptions about climate change and weather variability. The questions were structured to capture issues like causes, effect and the belief of the people about climate and weather variability. The accuracy of farmers' perceptions of climate change was assessed by comparing their perceptions of long-term changes in temperature and precipitation with climate trends from meteorological the regional data. Attitudes about the causes and effects of climate change were measured on a 5-point Likert-scale (Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree) was used.

2.4 Data Analysis

All responses from the interviews were analyzed through latent content analysis, a procedure that aims to identify themes and meanings from the data [24]. Data were coded based on the themes of perception, adaptive capacity and exposures to which producers are sensitive. The extreme climatic coincidence (precipitation and temperature) and/or annual climatic change trends were analyzed by comparing with the climatic data and the primary data and secondary data collected from literatures. The annual precipitation and temperature trends were analyzed using Excel and SPSS statistical package.

The next step in the statistical analysis was to compare households "with" and "without" barrier to climate change adaptation strategies on demographic, socioeconomic, income and coping strategy variables. Households with lack of information, lack knowledge concerning appropriate adaptations about climate change, no access to credit and lack market access were categorized as "barrier" households. Descriptive statistics were used to analyze socioeconomic characteristics of the respondents. Evidence of association between socioeconomic/ demographic variables and attitudes was explored by cross-tabulation and measured using Chi-square analysis.

3. RESULTS AND DISCUSSION

3.1 Socioeconomic Characteristics of Respondents

The 200 respondents included in the study comprised 122 females (61%) and 78 males (39%). The modal age range is 30-40 years (39%), most of them are married (73%), with majority of the household size (48%) being between 6-10 (Table 2).

Table 2. Respondents' distribution by socio-economic characteristics

Household characteristics	Frequency	Percentage of respondents
Age (years)		
30 – 40	78	39
40 – 50	74	37
50 – 60	32	16
60 – 70	10	5
≥ 70	6	3
Marital status		
Single	33	16.5
Married	146	73
Divorced	6	3
Widow(er)	15	7.5
Educational level		
No formal education	23	11.5
Primary education	88	44
Secondary education	38	19
Tertiary education	51	25.5
Gender		
Female	122	61
Male	78	39
Household size		
≤ 5	84	42
6– 10	96	48
>10	20	10
Average monthly income (FCFA)		
≤ 100,000	76	38
100,001 – 500,000	112	56
500,001 – 1,000,000	10	5
≥ 1,000,000	2	1
Access to credit		
No	144	72
Yes	56	28
Access to extension services		
No	156	78
Yes	44	22

1USD equivalent to 450FCFA as at 2012. (Field Survey, 2012)

An age range of 30-40 years indicate that majority of the households in the region are in their active working ages. The males have ownership over the land, the farming sector is dominated by women. The average household size was seven (7) signifying that the size was fairly large enough to influence the adoption of a new technology significantly as well as assisting to reduce labour intensive and costs in the long run.

Education is one of the key variables structuring farmers' decisions of an adaptation method. The nexus between increase in awareness with increase in age, level of education and farming experience is understandable given that climate change is a long term phenomenon that can only be apprehended and understood with time and practical experience. Also, literacy permits access to climate change awareness information not usually available to non-literates.

Quite a large number of the respondents (56%) earn 100,001 – 500,000 FCFA per year from their arable crop produce and this is significantly different between households "with" and "without" barrier to adaptation to climate change adaptation strategies ($\chi^2_{(0.05,3)}$=2.177, *P*=0.03). Wealth is believed to reflect past achievements of households and their ability to bear risks. Thus, households with higher income and greater assets are in better position to adopt new farming technologies.

Only 28% and 22% had access to credit (both formal and informal) and extension services respectively. Access to rural services such as extension and credit also increases the likelihood of adaptation. It also increases the likelihood that farmers will diversify their portfolios and buy feed supplements for their livestock. Farmers with access to extension services and who are therefore more likely to have knowledge of management practices to address climate changes were more likely to diversify their portfolios in an effort to reduce risk.

3.2 Seasonality According to Different Perspectives

3.2.1 From meteorological records

The Bamenda highlands experiences only minor seasonality with mean annual precipitation from 2400 to 3000 mm in an average year. Similarly, mean annual temperature varies from 18.7° to 21℃ (Fig. 2).

Precipitation trends during the growing season from February to April showed that annual rainfall data in the study area had been in declining trends for the past seasons since 1980 (Fig. 3).

However, total rainfall during this season appears to decrease at non-significant rate (R^2 = 0.062; P >0.124). The most affected months are February (R^2 = 0.0173, P>0.12) and March (R^2 = 0.034, P>0.056).

3.2.2 According to local farmers' perceptions

Climate change meant different things to farmers. Some attributed it to reduced rainfall/drought (20.7%), others to increase temperatures (20.3%), while as little as 4% had no idea. Of the 96% who identified a definition for climate change, 84% agreed that they have been experiencing the phenomenon for the past two decades and more with human activities and civilization (51%) thought to be the main causes (Table 3).

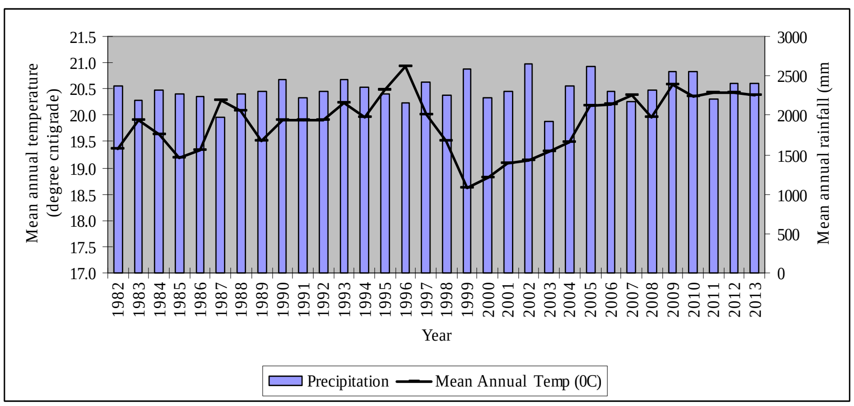

Fig. 2. Mean annual temperatures and precipitation in the Bamenda highlands based on field data

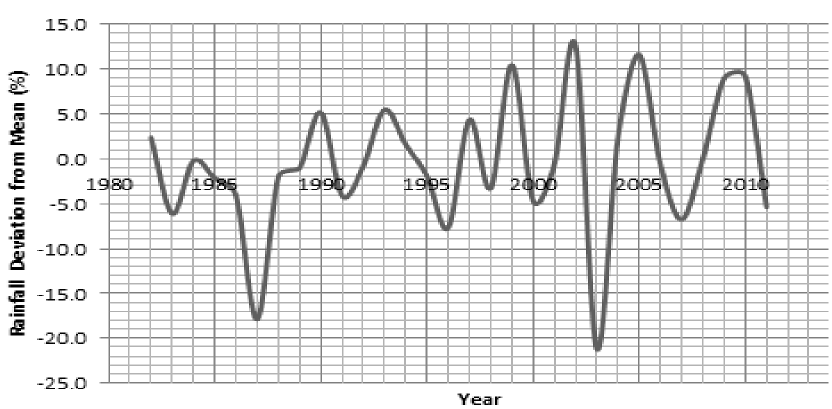

Fig. 3. Annual rainfall deviation (%) from the mean (2320.26 mm) for the Bamenda Highlands

Table 3. Perceptions of causes of climate change

Variables	Frequency	Percentage
Madam/ Daddy, in your opinion, what do you understand by climate change*		
▪ God's work	78	13.0
▪ Reduced rainfall/drought	124	20.7
▪ Increase temperatures	122	20.3
▪ Change in the periodicity/pattern of rainfall	66	11.0
▪ Prolonged dry season	98	16.3
▪ Cutting down trees	88	14.7
▪ I don't know	24	4.0
Has there been any change in climate in the last 20 years?		
▪ Yes	168	84
▪ No	32	16
What do you think are causes or reasons for climate change*?		
▪ Changing rainfall and temperatures patterns	86	18.3
▪ Men's sins	68	14.5
▪ Increased population	44	9.4
▪ Men's activities	142	30.2
▪ Civilization/modernization	98	20.9
▪ I don't know	32	6.8

**Multiple response questions*

Farmers often referred to the Bible arguing that disobedience of humankind to God's principles and/or lack of respect to ancestral spirits and other customs caused climate change. The second most common set of causes was associated with environmental explanations that identified deforestation, pollution from industries and modernization as causes of climate change.

With regard to climatic variables, below-normal rainfall years are occurring more and more frequently, resulting in poor harvests especially with the lack of early-maturing and drought-tolerant varieties. Shortage of dry-season fodder has also become a major impediment to livestock production, exacerbating food and income insecurity in the region. There is general consensus among farmers in the region that these have increased over the past decades with dry seasons becoming hotter and drier while rainy seasons colder (Table 4).

The perceptions on temperature and rainfall are confirmed by the foregoing local statistical record for the region for the past decades (1945 to date). Research has suggested that the risks of diarrheal disease may be augmented, and potential child-health impacts such as gastrointestinal disease, malnutrition, and psychological trauma are likely to increase with higher temperatures [28].

3.2.3 Perceptions of changes in the onset and offset of seasons

Most farmers experienced changes in the onset of the dry season (40.55%) and the rainy season (54.78%). Similar trend were observed on the offset of seasons (Table 5).

Table 4. Perceptions of farmers to change in climatic variables (% of the respondents)

	Perception		
Climatic variables	**Increased (n=200)**	**Decreased (n=200)**	**Stayed the same (n=200)**
Temperature:			
- Cold	83	12.3	4.7
- Hot	23	28	24
Rainfall	57	30	13
Extreme events:			
- Drought	57.3	27	15.7
- Floods	52.6	12.4	34.3
Duration of seasons:			
- Dry	80	3.2	16.7
- Rainy	80	5.2	14.8

Table 5. Farmers' perceptions of changes in the onset and offset of seasons

Perceptions	Dry season		Rainy season	
	Onset (n=400)	Offset (n=400)	Onset (n=400)	Offset (n=400)
Comes early (%)	40.55	9.23	54.78	58.99
Delays (%)	25.54	47.21	25.75	14.47
No change (%)	33.91	43.56	19.47	26.54

Most farmers felt that the rainy season started later and stopped later in the recent past as compared to a long time ago. In all the divisions, there was a general consensus that dry and extended spells are now more intense than decades ago. In the words of a key informant in the area,

> "*I can say that temperature is higher compared to 20 years ago. Our trees are drying up; young trees die and some of our agricultural crops like colocasia, cocoyams and bananas are being damaged by strange insect pests. Worst, we had watched our streams dry and spent sleepless night taking turns in fetching water from distant water sources that had managed to survive the drought. Stream biodiversities including butterflies have disappeared, and we could hardly see fishes which use to inhabit most of our streams".*

Farmers further reported late onset and end of rain, with the onset and end of the rainy and dry seasons becoming more undefined. In the words of a key informant in the area,

> *"…….. the rains came on the first week of March and stopped in October each year, marking the beginning and end of the rainy seasons. But now our days, rains don't start until mid-April and or early May and sometimes extends way into the first weeks of December. At times we have excessive rain and strong winds, which sometimes leads to flooding. I cannot conclusively say when the rainy and dry season will start and end next year". Sometimes it rains continuously such that we cannot weed nor do any work. Other times instead of the rains reducing and stopping, it continues and sometimes falls heavily destroying our crops that were ready for harvesting. It is difficult to understand the rains nowadays.*

In general, villagers reported that they make decisions regarding hunting, or preparing and planting gardens based on their experiences and perceptions. They plant their vegetables during the wet season, but they need dry days to prepare the land. They decide when to plant their gardens based on the rain. They also pay attention to heavy rains for fear of flash floods. None of the informants predicted major changes in the region's climate in the next decade(s). Their focus was on interannual variability and current trends from what they had experienced (more frequent droughts, floods and whirlwinds).

3.3 Negative and Positive Effects of Climate Change

Negative effects of climate change were cited by 81.4% of respondents. The three most common negative effects were poor crop production (due to flooding, prolonged dry spells and droughts), poor livestock production (due to increased diseases) and increased food insecurity (Table 6).

Table 6. Areas where negative effects have been noticed

Areas where negative effects have been noticed	Count (%)
Poor crop production	25 (%)
Soil erosion	24 (%)
Increase in pests and diseases	36 (%)
Increase in household food insecurity	54 (%)
Poor livestock production	20 (%)
Increased suffering and poverty	13 (%)

Note: A multi response frame was used. Hence, total count is more than the number of respondents

Farmer's perceptions of production problems range from climate related factors: drought, floods, and wind (25.8%), plant diseases (15.8%), and insects (18.8%) (Fig. 4).

It had been predicted [24] that increased temperatures are expected to reduce crop yields and increase levels of food insecurity even in the moist tropics Due to these risks, farmers have been adjusting their farming practices. The agricultural practices also have both direct and indirect influence on crop productivity.

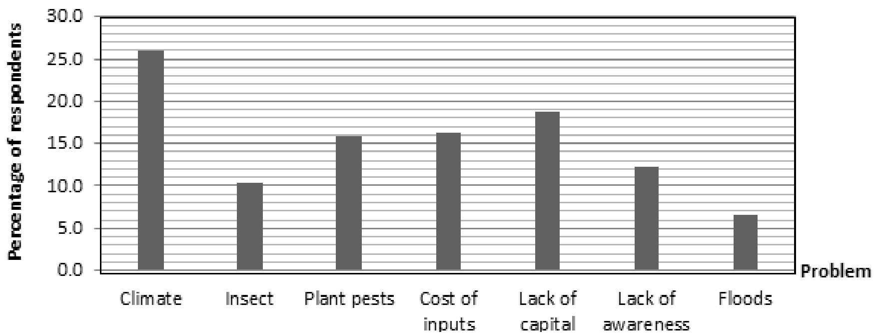

Fig. 4. Farmers perception of production problems in the Bamenda highlands, Cameroon

The 19.6% who perceived positive effects of climate change identified increased access to adequate water for both people and livestock due to floods (47%), increased and better crop production mostly through gardening (46%) and increased access to enough water and increased production of crops or livestock (25%) (Table 7).

Farmers explained that vegetable gardens were doing better because of increased water from flooding. Due to prolonged cold season, farmers explained that they could work more hours.

A critical observation of the responses suggests that certain factors seem to influence the likelihood that farmers will perceive climate change. Having fertile soil and access to water for irrigation decreases the likelihood that farmers will perceive climate changes, whereas education, experience, and access to extension services increase the likelihood that farmers will perceive climate changes. This suggests that perceptions are not based entirely on actual climate conditions and changes but are also influenced by other factors.

Farmers who have noticed increase in productivity concurs with slow but gradual increase of use of modern agricultural practices (especially organic farming) for the past 10 years as compared to the past 20 years. These agricultural practices were significantly observed in Bui division where the there is some degree of implementation of the activities of the non-governmental organisation, the Strategic Humanitarian Services (SHUMAS). The presence of this organization has led to a degree of conservation agriculture that has contributed to improved soil fertility management, increase of crops grown by the farmers, weed management as well as use of pest and disease control measures. Other studies have shown higher infiltration rates and water holding capacity in conservation agriculture plots than in conventional agriculture plots [29].

Conservation agriculture had been reported as potentially contributing in addressing the challenge of adapting agricultural practices to climate change [30]. It is an agricultural system involving minimum soil disturbance, permanent residue soil cover and diversified crop rotation [31]. It reduces negative impacts of climate change by optimizing crop yields and profits while maintaining a balance between agricultural, economic and environmental benefits [32-33].

3.4 Climate Change Adaptation Strategies

Understanding how local farmers experience climate variations and how they anticipate or react to them is likely to become crucial in the context of climate change. Some practices, such as mixed cropping and dispersal of sago and other crops in different locations, may provide some resilience (Table 8).

Table 7. Smallholder farmers' perceptions of positive effects of climate change

Areas where positive effects have been noticed	Counts (%)
Increased access to adequate water for both people and livestock due to floods	47 (%)
Increased access to enough water and increased production of crops or livestock	25 (%)
Increased and better crop production mostly through gardening	45 (%)
Increased and better livestock production	12 (%)
Increased household food security	12 (%)
Better crop and livestock production	17 (%)

Note: A multi response frame was used. Hence, total count is more than the number of respondents

Table 8. Ecological and socioeconomic adaptation methods employed by farmers

ID	Adaptation method	Frequency	Percentage
	No adaptation	10	1.1
1	Adoption of varieties with increased resistance to heat shock and drought	12	1.3
2	Use forest resources (Non timber forest products)	16	1.8
3	Planting of tree	24	2.7
4	Changing the planting dates	130	15.8
5	Early and late planting	52	5.8
6	Cultivation of short duration crops	74	8.2
7	Application of organic manures	126	14.0
8	Agroforestry practices	84	9.3
9	Traditional moisture holding practices (shedding, tillage, breaking top soil)	200	22.2
10	Mono-cropping abandoned for mixed cropping	172	19.1
	Total	900	100.0

While crop diversification, conservation agriculture and gardening are the common adaptation measures used by arable farmers, increasing livestock diversity and seeking support from veterinary officers are the measures taken by livestock farmers. Several reasons are behind diversification of farming activities as practiced by the grassland people, including the reduction of economic risk and provision of a more diverse diet, particularly from food crops. An anticipatory action to avoid flood damage was to locate gardens outside flood-prone areas, although issues regarding land rights sometimes encourage people to plant wherever they can, including on riverbanks.

One of the most important ecological and socioeconomic adaptation methods employed by farmers is the use of non-timber forest products. While honey is the most common NTFP exploited by farmers in Bui division, *Gnetum africanum, Irvingia gabunensis*, and many other NTFPs are extracted in Momo division. Wood and medicinal plants are common in all divisions of the region but the quantities are fast degrading especially in areas like Mezam division where uncontrolled urban sprawl is gradually extincting these products.

Elsewhere, indigenous people have used biodiversity as a buffer against variation, change and catastrophe; in the face of plague, if one crop fails, another will survive [34]. In coping with risk due to excessive or low rainfall, drought and crop failure, some traditional people grow many different crops and varieties with different susceptibility to drought and floods and supplement these by hunting, fishing and gathering wild food plants. The diversity of crops and food resources is often matched by a similar diversity in location of fields, as a safety measure to ensure that in the face of extreme weather some fields will survive to produce harvestable crops.

Several studies link exclusion from forest resources to vulnerability. For example, temperature increases and irregular rainfall in the Endau hilltop, Kenya, have led to decreased yields, crop failure, and water scarcity, severely impacting farmers and pastoralists without access to forest products such as wood, honey, herbs, bushmeat, and fodder [35]. In many coastal areas of South and South-east Asia, mangrove forest conversion or exclusion from access has increased the vulnerability of poor coastal communities. When mangroves are restored and accessible, people have access to diversified products (fish, firewood, timber, construction material, fodder, medicinal plants, and honey) and are more resilient to climate hazards, as was shown in Vietnam [36], in Bangladesh [34] and in the Philippines [37].

3.4.1 Traditional practices contributing to climate change adaptation in the region

3.4.1.1 Forestry

Local farmers considered local forests vital to their livelihoods (Fig. 5) for food (bush meat, gnetum leaves, and fruits), water (regulating water flow, protection of watersheds, and providing clean water), source of timber, firewood, agriculture, and as a reserve of products for future generations.

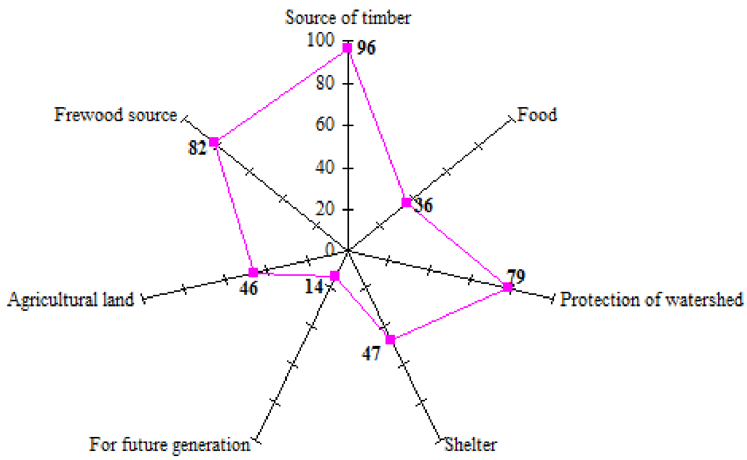

Fig. 5. Farmers' perception on the importance of the forest (based on multiple responses)

Generally, forests influence rainfall interception, evapotranspiration, water infiltration, and groundwater recharge. They contribute to regulating base flows during dry seasons and peak flows during rainfall events, both of which are services of utmost importance for the adaptation of people to climate variability and change. They are also important as sacred areas and for spiritual reasons. As a result, several forestry practices based on traditional ecological knowledge lead to the mitigation of climate change impacts in the region:

Trees around dwelling houses: Subsistence farmers in all the divisions surveyed had large scattered trees around their houses. These are an adaptive asset as they act as keystone structures over the landscape continuum and support dependent biodiversity as well as livelihoods. Trees can be beneficial for cash crops such as coffee and cacao as well. Coffee is sensitive to microclimate fluctuations, e.g., the optimal temperature range for Arabica coffee is 18–21℃ [38]. Shade trees control temperature and humidity fluctuations and can also provide protection from wind and storm events that defoliate coffee trees [39]. However, this practice diminishes as you move closer to the urban areas.

Sacred groves: They are common on very small scales around 95% of the chiefdoms in the Bamenda highlands. These do not only protect natural forest patches on religious norms, but also support flora and fauna in various agro-ecological zones. These green patches constitute a unique example of in situ conservation of our genetic resources. Such areas show microclimatic conditions with their own distinct floral and faunal values.

Sacred trees: Sacred trees are believed to be the dwelling place of god. These ecological and cultural keystones also support livelihoods. Unfortunately, the spread of Christianity is fast eroding this practice, felling the trees under the pretext that they are possessed by evil spirits. The absence of working conservation laws and other enabling conditions for environmental conservation are further threats to the environment.

3.4.1.2 Agriculture

Local farmers have been adapting to prevailing climatic conditions by selecting drought-resistant crop varieties, moisture-conserving cropping systems, mixed farming and agroforestry.

a) Mixed cropping: The practice includes sowing of different types of crops in combination with other practices of vegetation management. The practice reduces vulnerability due to monsoon and climate variability by ensuring some production.
b) Traditional agroforestry: Agroforestry has the potential to improve soil fertility. This is mainly based on the increase of soil organic matter and biological nitrogen fixation by leguminous trees. Trees on farms also facilitate tighter nutrient cycling than mono-culture systems, and enrich the soil with nutrients and organic matter, while improving soil structural properties. Through water tapping and prevention of

nutrient leaching trees help recover nutrients, conserve soil moisture and improve soil organic matter. The contributions of agroforestry systems are diverse including:

i. biodiversity conservation;
ii. yield of goods and services to society;
iii. augmentation of the carbon storage in agroecosystems;
iv. enhancing the fertility of the soils; and
v. providing social and economic well-being to people

Relationship between adaptation, assets, and multiple stressors become more discernible from the perspective of agroforestry. Growing trees and crops together in farmlands is useful in maintaining production during both wetter and drier years. During the drought deep root systems of trees are able to explore a larger soil volume for water and nutrients, which will help during droughts. Furthermore, increased soil porosity, reduced runoff and increased soil cover lead to increased water infiltration and retention in the soil profile which can reduce moisture stress during low rainfall years. Tree-based systems also have higher evapotranspiration rates and can thus maintain aerated soil conditions by pumping excess water out of the soil profile more rapidly than other production systems. Finally, tree-based production systems often produce crops of higher value than row crops. Thus, diversifying the production system to include a significant tree component may buffer against income risks associated with climatic variability.

3.4.1.3 Livestocks

Crop-livestock systems are the most prevalent agricultural land-use systems in the Bamenda highlands of Cameroon and the main livelihood strategy. The Fulanis earn their living almost exclusively from raising cattle, goats, sheep, and horses in a free-ranging farming system in the hills. During prolonged dry seasons herders generally have less access to fodder for their animals. They have therefore adopted a number of adaptation strategies inorder to cope with such unfavourable conditions:

- Some have switched to off-farm income generating activities and have reduced the number of livestock, by slaughtering and/or selling them during extended drought periods and restocking after the drought. Some other livestock farmers have switched to livestock that can withstand water stress and hot temperatures (poultry).
- In the most recent past, some have migrated well down the valleys, where there is generally more moisture to support vegetation. Some move to the riparian vegetation where there are often favorable conditions for the growth of vegetation. This practice, however, often has a lot of negative externalities. Of particular importance is the contamination of water resources by faeces and urine from the cattle that eventually increase the concentration of faecal coliforms in streams. In most cases, food crops and vegetables are often destroyed leading to the common farmer-grazer conflict in the region. At the same time, should herders not do so, they risk losing many cattle, their milk production will be very low, and their incomes and livelihood threatened.

3.5 Barriers to Climate Change Adaptation in the Region

Barrier to climate change is here defined as obstacles that delay, divert, or temporarily block the adaptation process, but which can be overcome with concerted efforts, creative management, change of thinking, prioritization, and any related shifts in resources, land uses, or institutions. The farmers identified lack of information on climate change impacts and adaptation options, lack of access to credit, access to water, high cost of adaptation, insecure property rights and lack of access to sufficient farm inputs as the main barriers to the adoption of any adaptation measure (Table 9).

Farmers expressed the view that among many of the sources of information, agricultural extension is the most important for analyzing the adoption decisions of adaptive measures. The results agree with the hypothesis that farmers who have significant extension contacts have better chances of being aware of changing climatic conditions as well as adaptation measures in response to the changes in these conditions [40]. Managing the connections among agriculture, natural resource conservation, and the environment must be an integral part of using agriculture for development.

Access to credit also increases the likelihood that farmers will diversify their portfolios and buy feed supplements for their livestock. It also increases financial resources of farmers and their ability to meet transaction costs associated with various adaptation options they might want to adopt. Other barriers to climate change adaptation technologies were found to include; high cost of adaptation measures and insecure property rights growth in parts.

3.5.1 Associations between barriers to climate change adaptation strategies with demographic and socioeconomic factors and coping strategies

On the demographic and socioeconomic characteristics, famers “with” and “without” barrier to climate change adaptation strategies differed significantly on most of the independent variables (Table 10).

In general, households with barrier to climate change adaptation strategies were characterized by larger household size, more children, low income, less access to credit, low household income. Although the farmers did not differ significantly on perceptions of income stability, more of the farmers “with barrier” reported short and long term income instability. The common responses for income instability were fluctuations in prices for agricultural commodity items such as cocoyams, plantains, potatoes, drying off and pollution of streams and rivers which affects fish catch and difficulty to do odd jobs or secure secondary employment to supplement.

It is recognized that in developing countries, women are closest to nature and therefore play an important role in ensuring climate change mitigation. They are involved in household food production, participate in economic activities so as to supplement household incomes and are responsible for the care of the household members. In our study, more women who had access to climate information were income-earners and being a housewife was a significant factor associated with barrier to climate change information. The combination of their working experience (socialization with other people) and ability to generate and control financial resources in the households may allow them to provide enough food for family members, manage income and food resources efficiently and be innovative in coping with household income or climate change risks.

Table 9. Barriers to adaptation in the Bamenda Highlands

Barrier / Division	Lack of information about climate change	Insecure property rights	Lack of knowledge concerning appropriate adaptations	Poverty or lack of credit or savings	High cost of adaptation measures	No barriers	Total
Mezam, N (%)	5(11.1)	4(8.9)	10(22.2)	8(17.8)	6(13.3)	12(26.7)	45(100)
Ngoh-ketunjia, N (%)	8(15.1)	8(15.1)	10(18.9)	10(18.9)	8(15.1)	9(17.0)	53(100)
Momo, N (%)	9(17.6)	5(9.8)	8(15.7)	7(13.7)	8(15.7)	14(27.5)	51(100)
Bui, N (%)	7(13.7)	6(11.8)	9(17.6)	9(17.6)	10(19.6)	10(19.6)	51(100)
Total	29(14.5)	23(11.5)	37(18.5)	34(17)	32(16)	45(22.5)	200(100)

Table 10. Demographic/socioeconomic characteristics of farmers “with” & “without barrier” adaptation strategies

Characteristics	Without barrier (n = 144)	With barrier (n = 56)	p value*
Household size *Mean* (SD)	5.4 (1.6)	7.7 (1.9)	< 0.001
Years of schooling (father) *Mean*	5.5 (2.6)	11.7 (2.3)	< 0.001
Years of schooling (mother) *Mean* (SD)	4.5 (2.3)	7.1 (2.5)	< 0.001
Household income (FCFA) *Mean* (SD)	53954.9 (37354)	87450 (41252)	< 0.001
Income per capita (FCFA) *Mean*(SD)	7125 (2542)	13654 (6458)	< 0.001
Access to credit/Savings *N* (%)	79 (94.0)	93 (80.2)	< 0.001

**Value is based on T-test or Chi-Square analysis for comparison of group mean differences and percentages of households within each group with such characteristics, respectively. SD: Standard Deviation*

4. CONCLUSION

Farmers in the Bamenda highland of Cameroon are adapting to changing circumstances with climate parameters playing a key role in their decision-making, though there are still a number of barriers to adaptation strategies. Our findings shed light on the urgency of mitigating greenhouse gas emissions if climates potentially harmful to biodiversity and society are to be prevented. This study has also shown that there is also a major improvement in knowledge and access to agricultural information among farmers with improved but inadequate access to media in the region. Though households in some divisions, especially in Bui observe positive major changes in their farming practices largely because of the heavy presence of a development NGO (SHUMAS), their productivity is still low.

The research findings also underline the importance and need for local knowledge in several ways:

- Smallholders do perceive their microclimate variations and are able to cope and adapt. There is an urgent need for the integration of local knowledge in critical climate policies to improve agricultural practices. For example, smallholders adapt to drought through an array of adaptations such as crop diversification, sale of livestock, migration and search of employment.
- The views of the farmers suggest that people's perceptions and their agricultural practices provide insights to what smallholders really need and prefer in adapting their agriculture to climatic variability. Smallholders' knowledge points out what needs to be improved to enhance adaptive capacity, for example, access to veterinary services.

The variability in yield response in this region, and the variability in households' ability to adapt, suggest that, even given the limitations of this analysis, adaptation options need to be assessed at the level of the household and the local community, if research for development is to meet its poverty alleviation and food security targets in the face of global change. However, the potential consequences of an increase in further greenhouse gases emission are still not fully explored, but further temperature increase, changes of rainfall and more frequent extreme weather events are predicted. These factors raise the risks of ecological changes and the vulnerability of ecological systems in the region.

There is need for a National Climate Change Response Strategy that will put in place robust measures needed to address most, if not all, of the challenges posed by climate variability and change. The Bamenda highlands can benefit greatly from developing a strategy for REDD in synergy with a national policy on adaptation to harness the multiple benefits offered by REDD – reducing carbon emissions, protecting forests for biodiversity, facilitating ecological adaptation on land and maintaining other critical ecosystem services. A sound regional strategy on REDD could bring benefits to local communities from REDD investments and build a strong foundation to undertake mitigation and adaptation activities in tandem.

Plant breeding has the potential to play an important role in climate change adaptation. Encouraging local researchers and building strategic partnerships involving international research organisations, national programmes, the private sector and community based organisations is an important strategy. When backed by workable development agencies, can be effective in developing, testing and releasing new crop varieties that are adapted the changing climatic conditions.

Communicating and enhancing the public awareness about vulnerability as well as individual/collective adaptive actions is critical. Awareness raising and communication with different stakeholders to create understanding and catalyze public participation and adoption of adaptation actions is essential. Raising public awareness will be a catalyst for any planned government interventions, enhancing society's risk perception, eliciting possible adaptation action by policy makers and the public or preparing society for anticipated impacts of climate change.

Given that few farmers adjusted their farming practices despite perceiving changes in climate, governments should facilitate adaptation by enabling farmers to overcome the barriers reported in this study. Specifically, policies should ensure that farmers have access to affordable credit, which would give them greater flexibility to modify their production strategies in response to climate change. Subsidizing farmers, capacity building and clearly defining property rights cannot be left out. Additional measures required are improving off-farm income-earning opportunities, and facilitating a smooth transition from subsistence to commercial farming.

There seem to be a contradiction between meteorological records and local perception. How formal measurements are taken, the precautions taken, frequency of measurements, the quality of weather instruments used and the qualification of those responsible for such measurements is yet to be investigated and is important for future research.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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