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FROM CLIMATE RISK ANALYSIS TO AN ENVIRONMENTAL SAFETY SYSTEM IN THE BAMENDA HIGHLANDS OF CAMEROON

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ABSTRACT

This cross sectional study aims to analyse climate change risks in the Bamenda highlands of Cameroon, and propose an environmental safety system for the region. A twenty-five year climatic data (rainfall, temperature, evaporation, relative humidity, sunshine hours), and crop yield statistic over the same period (1991 to date) were collected. Field visits and focus group interviews with some 140 farmers purposely selected complemented the database. Multiple regression analysis was used to test if the climatic variables significantly predicted change in agrobiodiversity. On average, the mean annual temperature of the region increased by 0.04^0C per year. Human health impacts of this temperature rise included heat cramps (11.2%), heat exhaustion (68.3%) and death (20.5%). Other impacts range from increasing droughts to shifting agricultural calendars in unpredictable ways. Because of droughts and floods (1) streams that once served as sources of potable water are now filled with mud/silt, and some have either completely dried up or become seasonal and not suitable for drinking anymore. This has forced many people to either drink polluted water or move through long distances in search of potable water especially during the dry season; (2) aquatic habitats and biodiversity are being destroyed. The African lungfishes, *Protopterus annectens*, for example, that was once a common catch and cheap source of protein for households are now rare to near extinction, especially in urban and peri-urban areas; (3) yields of a number of subsistence crops such as *Colocascia spp.*, *Colocasia esculenta*, *Zea* *mays*, and cash crops such as tea (*Camellia sinensis*) are on the decline. The two predictors, temperature and precipitation explained 43% of the variance in yield (R^2=.43, F (2, 140) =5.56, p<.01). It was found that rainfall significantly predicted crop yield (β = .56, p<.01), as did temperature (β = -.36, p<.01). Declining yields have led to high prices of food items in the market, undermining food security. To cope with and mitigate the adverse effects of climate change risks, the model of complex environmental safety system is proposed. This model could be instrumental to the development of heat and drought-resistant high-yielding crop varieties.

KEYWORDS: Loss and damage; climate change; environmental safety system; food security.

INTRODUCTION

Worldwide, weather and climate-related loss and damage have increased dramatically over the past few decades (Thornton et al., 2011). It also contributes to increased climate extremes and exacerbates adverse impacts on societies and ecosystems in combination with other environmental, economic and political stresses and this, of course, adds to the complexity (Granberg and Glover, 2014). While there is no official definition, loss and damage usually refers to the 'residual effects' of climate change that cannot (or will not) be avoided through mitigation and adaptation (UNFCCC 2016). This includes impacts related to extreme weather events (such as flooding, droughts, or cyclones) and slow onset events (such as sea-level rise, desertification, or melting glaciers). These climate-related risks raise important concerns regarding the future sustainability and resilience of certain crops in Africa, since agriculture plays a multifunctional role in integrating natural resources management, rural development and food production and underpinning environmental heritage through the maintenance of semi-natural habitats, landscape and biodiversity. Knowledge of likely climate - related hazards and their interactions in specific locations with the existing and future population and different kinds of assets enables the planning of adaptation n me as u res and provides a rationale for their implementation (Oppenheimer et al 2014). Vulnerability and risk assessments that combine physical and socio- economic information to show climate change risks in a particular area or a sector have become a way to address the need for this knowledge (Preston et al 2011). The Sensitivity, Exposure and Vulnerability (IPCC 2014) of mountainous grasslands prove the urgent need for the analysis of ecological risks, exposure and effects, their relationship with each other, as well as the necessity for the revision of the environmental law.

The overall risks of climate change impacts can be reduced through mitigation, i.e. by limiting the rate and magnitude of climate change. However, even under the most ambitious mitigation scenarios, risks from adverse climate impacts remain, due to already locked-in climate change. Therefore, adaptation policies and measures anticipating a wide range of potential climate-related risks are essential. Currently, responses to climate-related pressures and hazards are often limited to short-term and reactive local emergency measures. However, building environmental and socioeconomic resilience against climate change at the regional level is about pro-active, longer term and integrated planning that addresses existing aspects of unsustainable development as drivers of vulnerability and guides the economic development of the region in a more sustainable direction. As climate risks extend well past territorial boundaries, a cross-border collaborative and coordinated regional approach to adaptation is required, promoting synergies with other multilateral environmental agreements.

As a response to these developments, the IPCC recently introduced the concept of climate risk, which includes hazard, exposure and vulnerability, in its Special Report Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation and in the Fifth Assessment Report (Cardona et al 2012, Oppenheimer et al 2014). Internationally, there is increasing recognition that adaptation and mitigation will not be enough to address the adverse impacts of climate change. Residual loss and damage will occur where limits of adaptation are reached. Against this background, loss and damage has gained growing attention under the United Nations Framework Convention on Climate Change (UNFCCC) and led to the establishment of the Warsaw International Mechanism for Loss and Damage (UNFCCC, 2016). In 2015, Parties to the Convention recognised the ‘importance of averting, minimizing and addressing loss and damages. Thus, the Paris Agreement emphasised this importance by introducing L&D as a standalone article under the UNFCCC, in addition to mitigation and adaptation.

We argue that one crucial factor has received little attention so far: the approaches and methods used to date for risk assessment and management do not take adequate account of loss and damage, the associated (non-) economic costs or slow onset events brought about by climate change. This underscores the challenges involved in developing and rolling out comprehensive methods and measures for assessing and managing climate change risks. We also emphasise on the need for an environmental safety system for integrated management of climate related risks. The ultimate objective of the environmental safety system is to ensure capacity building at all levels to reduce and respond to the new and exacerbated challenges that loss and damage poses, as well as coordination between agencies, organizations, and other groups. This could ensure the availability of goods and services provided by terrestrial and aquatic resources on a sustainable basis. In this way conflicts related to the use of the goods and services generated by the ecosystems will be minimized through a coordinated program of action conducted jointly by the communities. Specifically the paper aims to:

1. Classify climate-related risks (loss and damages) along the continuum between extreme events and slow-onset in the Bamenda highlands of Cameroon.
2. Develop an environmental safety system for integrated management of climate related risks in the region.

MATERIALS AND METHODS

Study Area

The Bamenda highlands lies 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, to the south-East by West Region, to the North East by the Adamawa Region, and to the West and North by the Federal Republic of Nigeria (Fig 1).

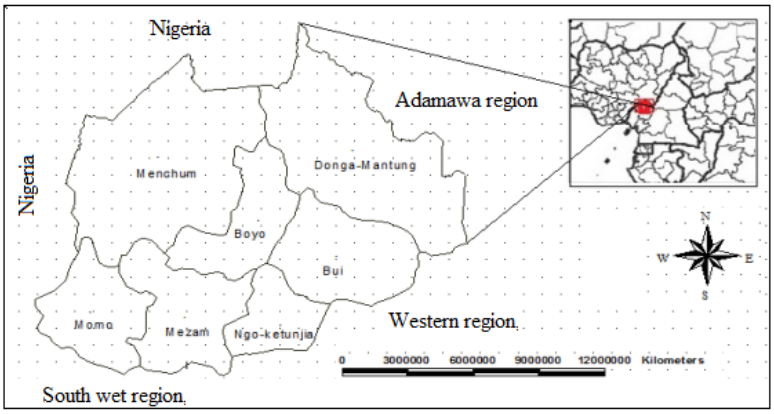

Figure 1: Location of the Bamenda Highlands region, Northwest Province, Cameroon.

The region is characterized by accidental relief of massifs and mountains. It features several dormant volcanoes, including the Mount Oku of all (Ndoh et al 2015). The plateau gives way to the Adamawa Plateau to the northeast, which is a larger but less accidental region. A cool temperate-like climate, influenced mainly by mountainous terrain and rugged topography also characterize the region. Average rainfall is about 2400 mm, temperature average 23^0C, ranging between 15^0-32^0C (Ndoh and Ge, 2005). There two main seasons; wet season, which starts in April and ends in October, and dry season from November to February. The dry season is characterized by the Hamattan with dry air.

Because of this range of ecosystems and associated habitats, the Bamenda highlands have a wealth of biodiversity. To a great extent, its natural history is unique. The high population density in many parts of the region has kept it relatively pristine, although there is little information on the potential future impact of human migration trends and the spread of agriculture in the region.

Forests once largely covered vast area of the Bamenda Highlands region of Cameroon. However, the forests were progressively cleared for farmland and grazing until today only patches remain. Although small, these patches are recognized as globally important sites for conservation of biological diversity. At the same time, the forests are very important for the people living around them, as they supply water, fuelwood, medicines, honey and other products and have cultural and spiritual importance.

Methodology

This was essentially a qualitative cross-sectional study. The participation of qualified experts and stakeholders is of paramount importance in defining and selecting regional planning objectives. Hence purposive snowball sampling (Hay, 2000) was used to select the participants. As an integral part of the process of formulating the environmental safety system for the Bamenda highlands, the participants consisted of men and women of the regional planning, forestry, environment, higher education corps and the local councils.

Research was conducted in three of the seven divisions that make up the North west region especially vulnerable to loss and damage due to climate variability and climate change (Mencnhu, Ngoketunjia and Mezam). Quantitative and qualitative data was gathered through household surveys (n = 80) and more than a 15 focus group discussions and interviews with key informants about their personal experiences of climate change impacts and about their responses. An overview of the research area, climate stressors, societal impact and sample size is shown (Table 1).

Table 1: Sample points: climate stressors, societal impact and sample size.

Division	Climate-related stressor	Societal impact focus	Sample size
Mezam	Drought and flood	Drinking water + Habitability + Crops + livestock + fish	34
Menchum	Drought and gas emissions	Livestock + fish	22
Ngoketunjia	Flooding	Drinking water + Habitability + Crops + livestock + fish	24
Total			80

The sites were selected to cover a wide range of ecosystems, geographic regions (mountains, plateaus) and climatic stressors (droughts, floods, gas emissions, changing rainfall patterns) as well as dependence of livelihoods on climate conditions (e.g., rainfed agriculture, fishing, herding). Other important considerations included exploring cross-cutting issues related to climate stressors, such as food production, human and livelihood security, social justice and cohesion, and human mobility.

Primary data was collected from field observations, interviews/focus group discussions. and local people (village regents, youth leaders, and women's group representatives. The selected stakeholders participated in focus groups to identify and prioritize the criteria for environmental safety system. The following stages: identification of the basic constraints to the effective ecological safety system implementation, analysis of the ecological risks, and elaboration of the complex environmental safety system for the Bamenda highlands of Cameroon.

RESULTS AND DISCUSSIONS

On average, the mean annual temperature of the region increased by 0.04^0C per year for the past 26 years. On the other hand, average annual rainfall is expected to decrease drastically below 1200mm per year.

Current Climate Change Impacts/Risks

Climate-related stressors are widely experienced in the research sites ranged from floods, droughts, food security and livelihoods and human health.

Flood risk

In recent years (up to the time this paper is being written), flooding (mostly from July to August) is causing devastating effects in some areas especially riverine locations (Fig. 2).

Figure 2: Abandoned house in Sisia quarter, Nkwen-Bamenda.

The social impacts of the 2012 Babessi floods (Balgah & Buchenrieder 2014) noted that the floods completely destroyed 26 homes and rendered over 50 families homeless, and livelihood assets destroyed. Increasingly frequent deluges disproportionately affect those living in informal settlements. People cried as they looked at the damage under steady rain, gesturing towards a flooded lowland where dozens farmlands and houses used to stand. The devastating effects of floods on the indigenous population are enormous, ranging from destruction of properties to human deaths (Table 2).

Table 2: Devastating effects of floods in some area of Bamenda.

Year	Affected area	Flood events
1995	Mulang, Small Mankon, Ndamukong, Below Foncha	Death of two people and destruction of property
1998	Old town valley, Ntamulung, Mulang, Below Foncha	3 deaths destruction of houses and farm lands
1999	New lay out, Old town valley, Ntamulung, Mulang, Below Foncha and Bayelle	1 death
2000	Ntamulung, Mulang, Below Foncha	3 death
2001	Ntamulung	1 death
2004	Below Foncha and Musang	1 death
2005	Musang, Mulang, Below Foncha and Ngomgham	Death of one child and destruction of property
200 to date	Below Foncha, Mulang Ntamulung, old town, Sisia, New layout	2 deaths recorded. Destruction of property and farmland

The Babessi floods of 2012 also resulted to substancial losses on assets (Table 3).

Table 3: Changes in value of selected physical assets resulting from the 2012 Babessi floods.

Variable	Time frame	Mean	Standard deviation	*P*-value
Value of television set(s)	Before floods	39 080	48 140	0.007
	After floods	7895	16 990	
Value of radio sets	Before floods	3140	9175	0.092
	After floods	465	1690	
Value of chairs	Before floods	87 270	104 675	0.022
	After floods	42 085	42 085	
Value of cupboards	Before floods	18 890	48 745	0.183
	After floods	2430	10 905	

Apart from direct impacts, for instance, on agricultural production and assets, floods are known to have serious direct and indirect social, psychological and other effects on victims. Such effects may be caused by the loss of human lives, the spread of faecal and vector-borne diseases, mental disorders and other forms of psychosocial traumas that often accompany floods or persist after such events occur (Abuaku et al . 2009).

It should be noted that very few incidents of floods were recorded in Bamenda highlands before 1980. Despite heavy rains in the months of July, August and September, most streams were capable of containing large volumes of water within their channels. Though the expanding population of Bamenda is a vital source of development, it brings with it plenty of hydrological problems especially when it exceeds the threshold limits of the support system. Population increase has come along with an increase in solid waste production, some of which is directly dumped into streams and storm drains, which are already too small to carry runoff. From field evidence, 55% of those sampled dump their waste in stream courses, 25% in drains, 15% at roadside dumps and 5% in the Bamenda City Council Van. These water ways are clogged by wastes and in the event of heavy rainfall, floods occur. Open dumps in streams and drains pose serious threat to groundwater resources and soil. Potential contamination of soil by heavy metals from waste products can cause adverse effects on human health, animals and soil productivity.

Drought risk

Droughts resulting from temperature anomalies are having great implications for water availability and shifting agricultural calendars in unpredictable ways. Droughts in the region are generally characterized by abnormal soil water deficiency. It is mainly caused by natural climatic variability, such as precipitation shortage or increased evapotranspiration resulting from deforestation. In the recent years, successive years of low precipitation have left large areas of the region in severe drought that resulted in water shortage in the region. Streams that were once used as sources of potable water a now filled with mud silt (Fig. 3), and some have either completely dried up or become seasonal, and not suitable for drinking anymore forcing people to either drink polluted water or move through long distances to search and fetch water, especially during the dry season.

Figure 3: Typical water resources in Bamenda city during dry seasons.

Recent studies have found significant linkages between climate change and surface water quality. Lunchakorn, Suthipong, and Kyoung (2008) applied Pearson's correlation to determine the relationship between climatic, hydrological and water quality parameters in downstream Mekong River flows through four countries (Lao, Thailand, Cambodia and Vietnam). The research found significant correlations between the studied parameters, in which rainfall, mean water level, discharge flow and mean air temperature have relative positive correlations with total suspended solid (TSS), NO_3^-, $PO4^{3-}$, total phosphorus, and chemical oxygen demand (COD) of water.

The siltation of rivers and streams has serious impacts on aquatic habitats and biodiversity. Currently, local fishes, *Protopterus annectens*, commonly known as *“*mudfish*”* rare to near extinction in water bodies, especially those in urban and peri-urban areas. It is difficult to make a catch today compared to the past when local fishermen (using hooks) would make over a hundred catch per night. This means a lot on local livelihoods and nutrition. With the changing climate, changing hydrological regimes may induce the growth of invasive species and expansion of diseases in the ecological system. The situation on livestock has been catastrophic especially the case of the Lake Nyos disaster (Balgah & Buchenrieder 2014) of and the recent Babessi floods of 2012 (Table 4).

Table 4: The impact of the Babessi floods on Livestock assets.

Variable	Time frame	Mean FCFA	Standard deviation	*P*-value
Value of cattle (FCFA)	Before floods	123 075	401 615	0.099
	After floods	61 540	227 535	
Value of small ruminants (FCFA)	Before floods	144 105	401 615	0.030
	After floods	58 590	161 955	
Value of pigs (FCFA)	Before floods	135 895	246 055	0.026
	After floods	57 690	155 030	
Value of poultry (FCFA)	Before floods	51 925	67 985	0.001
	After floods	8925	16 250	
Value of other livestock (FCFA)	Before floods	3140	9175	0.092
	After floods	470	1690	

The Risks of Climate Change for Crop Production: Food security and livelihoods

In terms of the risk of climate change to the production of individual crops, one thing we wish to avoid is crop failure. This may be defined as: "Reduction in crop yield to a level that there is no marketable surplus or the nutritional needs of the community cannot be met." We assessed the projected impacts of climate change on the yield of six major crop types (*viz* Cassava, Bean, Yam, Cocoyam, Maize, and Potato) grown in in the region through interviews. Evidence of climate impacts on yield was extensive for cocoyams, cassava, maize, yam and potato, but very limited for the rest of the crops. While the yields of all these crops are declining, cocoyams are on a rapid decline and are projected to suffer the largest negative mean change. The decline is the result of a combination of factors of which climate induced pests is primordial. This fails to leverage with increase in the amount of agricultural inputs thus increasing hunger and poverty in the region. The major pests and diseases of crops include the yam anthracnose, sweet potato scab (*Elsinoe batatas*), taro beetle (*Papuana spp*), root fungus (Phytophtora), fruit piecing moth, fruit fly, and the giant African snail (Table 5).

Table 5: Bread crops that are vulnerable to climate change induced pests.

Crop (Local Names)	Scientific name	Indicators	Observed impact
Taro Cocoyam	*Calocasia esculenta*	Attacked by fungi	Leaves rot and the tuber decay completely in the soil. This crop is threatened since 2010
Ibo Cocoyam	*Colocascia spp.*	Attacked by fungi	Leaves rot and the tuber decay in the soil. going extinct since 2010
Palm tree	*Elaesis guineesis*	Slow pollination on plant	Drop in productivity, increasing the cost per litre of palm oil.
Yam	*Dioscorea spp.*	Leaves dry up	Productivity dropped
Maize	*Zea mays*	Slow pollination, easily attacked by insects and fungi	Productivity is dropping, use of chemical fertilizers and pesticides increasing
Pineapple	*Ananoise sativa*	Easily attacked by fungi	Productivity drops
Beans	*Vulgorus spp.*	Loss of leaves	Drop in productivity
Sweet potatoes	*Ipomea batatas*	Loss of leaves	Drop in productivity
Irish potatoes	*Solanum tuberosum*	Loss of leaves, easily attacked by blight and other pests	Drop in productivity
Plums	*Dacroides edulis*	Slow pollination	Drop in productivity

When the data for different studies were disaggregated, as in figure 4, the wide range of possible outcomes is more clearly visible.

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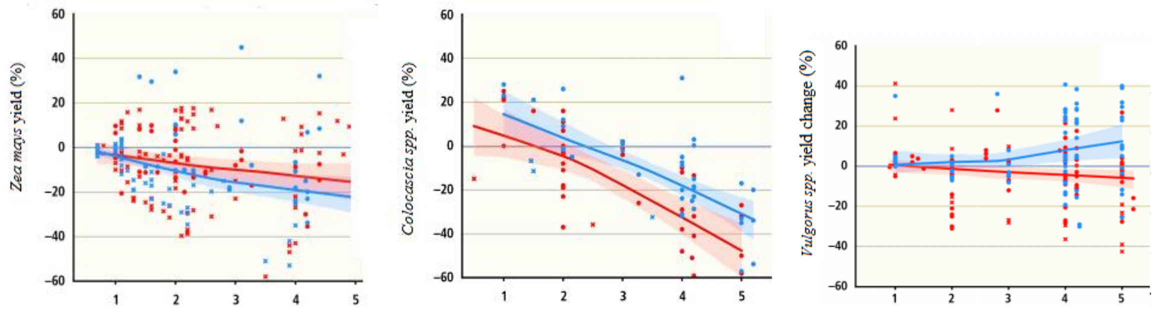

Local mean temperature change (^{o}C) Local mean temperature change (^{o}C) Local mean temperature change (^{o}C)

Figure 4: Percentage simulated yield change as a function of local temperature change for the three major crops for the region.

The two predictors, temperature and precipitation explained 43% of the variance in yield (R^2=.43, F (2, 140) =5.56, p<.01). It was found that rainfall significantly predicted crop yield (β = .56, p<.01), as did temperature (β = -.36, p<.01). Declining yields in turn lead to high prices of food items in the market. For example the price of corn has increased from15000-25000 FCFA[1] for a 100kg while groundnuts have increased from 42000-48000 FCFA (farmer's voice 2008/12). Similarly, Irish potatoes (*Solanum tuberosum*) that use to cost 25000 FCFA for about 250kg are now sold at 40000 FCFA and these prices are still increasing. Food security is potentially undermined where food price increases following harvest loss whether in regions neighboring or distant disproportionately affect the urban poor (Ahmed et al. 2009; Hertel et al. 2010).

In the Bamenda highlands for example, projected agricultural yield declines need to be seen in concert with potential decreases in protein intake due to declining fish catch potential. The job loss associated with projected declines in catches is on the rise. The situation is expected to increase especially with increase in deforestation, ecologically unfriendly agricultural practices, increase in corrupt practices, limited access to capital and technology and the current sociopolitical situation (Anglophone crises) in the region. Indirect consequences of climate change impacts on the different dimensions of food security in the region are shown (Table 6).

[1] 1USD = 550FCFA

Table 6: Indirect consequences of climate change impacts on the different dimensions of food security.

Dimension of food security	Indirect consequences of climate change
Availability of sufficient food	Reduced agricultural production. Decreased availability of forest resources. Increased pressure on food reserves. Decreased exports and increased imports.
Access to the resources needed to acquire food	Increased food price. Loss of incomes due to damage to agricultural production or interruption in livelihoods activities. Need to adjust agricultural practices and other livelihood strategies to manage uncertainty of changing hazards and conditions. Increasing migration to urban areas.
Utilization, including nutrition food safety and quality	Health impacts including food-borne diseases and malnutrition Dietary and nutritional changes based on changing availability of or access to preferred foods. Persons living with HIV&AIDS may experience difficulties in maintaining anti-retro viral therapies and may be more susceptible to infections. Impacts on food safety resulting from water pollution, increased temperatures and/or damage to stored food.
Stability of availability and access to food	Instability of food supplies (affecting both availability and pricing of food). Insecurity of incomes from agriculture and fisheries. Population displacement and migration. Potential for increased conflict over resources.

In recent years, the intensity of agricultural activities along river paths has increased. The removal of riparian (stream-side) vegetation in search of fertile agricultural lands not only alters habitat structure directly, but can have additional ramifications such as increased siltation and temperature rise. Increasing temperatures above 27°C (and soil water deficit) without the application of good farming practices, fertiliser application and the employment of irrigation in a very poor political enabling environment as such are likely to induce pollen sterility of certain crops with high night temperatures adversely affecting flower initiations with the ultimate effect on yield. The yield of cash crops in the region seem to be affected by key climate variables, temperature and rainfall (Fig 5 & 6).

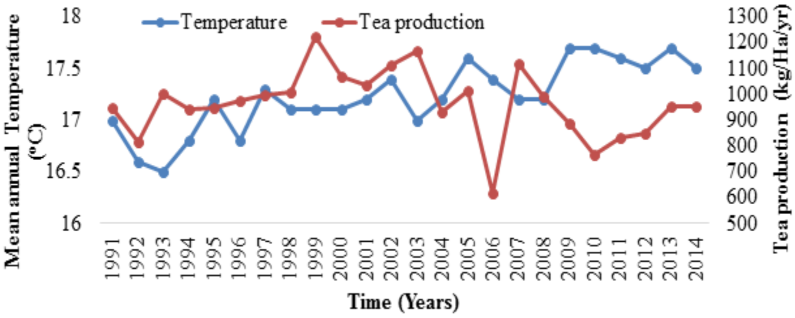

Figure 5: Relationship between annual temperature and tea yield.

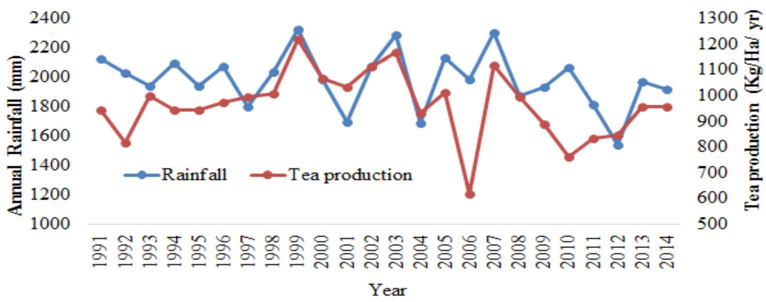

Figure 6: Relationship between tea yield and rainfall.

The high levels of dependence on precipitation for the viability of Sub-Saharan African agriculture, in combination with observed crop sensitivities to maximum temperatures during the growing season (Asseng et al. 2011), indicate significant risks to the sector from climate change. The IPCC states with high levels of confidence that the overall effect of climate change on yields of major cereal crops in the African region is very likely to be negative, with strong regional variation (Niang et al. 2014). Moreover, climate extremes can alter the ecology of plant pathogens, and higher soil temperatures can promote fungal growth that kills seedlings (Patz et al. 2008).

The pastoral systems of the Bamenda highlands are highly dependent on natural resources, including pasture, forest products and water, all of which are directly affected by climate variability. Livestock is an important source of food (such as meat and milk and other dairy products), animal products (such as leather), income, or insurance against crop failure (Seo and Mendelsohn 2007). Livestock is vulnerable to drought, particularly where it depends on local biomass production, and a strong correlation has been reported between drought and animal death (Thornton et al. 2009).

Human health

Extreme heat events can also have a direct impact on health by causing heat stress. Heat cramps (11.2%), heat exhaustion (68.3%) and death (20.5%), are among the cases identified in the region. Elsewhere, lengthy exposures to high temperatures have been found to bring about fainting, heat stroke and compromise outdoor human activities (Smith et al. 2014). Climate change impacts on agriculture are expected to undermine human health by affecting the affordability and availability of nutritious food. While levels of undernutrition are already high across the Sub-Saharan African region, projections indicate that with warming of 1.2–1.7^{0}C by 2050, the proportion of the population that is undernourished would increase by 25–90% compared to the present (Lloyd et al. 2011). Undernutrition places people at risk of secondary or indirect health implications by heightening susceptibility to other diseases (World Health Organization 2009).

Outbreaks of transmittable diseases, both food- and water- and vector-borne, can occur following extreme weather events such as flooding. Past outbreaks of cholera, which is associated with contaminated water and poor sanitation, have been observed to follow heavy rainfall events combined with elevated temperatures (Reyburn et al. 2011). Overall, an increase in the risk of malaria is projected for the region and estimates of additional people at risk are at thousands for under 2^0C warming, and to hundreds of thousands to millions under 4 ^{0}C warming.

Overall, environmental risks relating to the Bamenda highlands can be divided into three groups: natural-ecological, techno-ecological and socio-ecological, with due regard to the influencing factors, as well as natural and climatic conditions of the region (Table 7).

Table 7: Environmental risk classification within the Bamenda highlands, description and effects.

	Risk type	Description	Effects
Natural-ecological	Methane Emission	Methane emissions from streams/rivers owing to waste dumping likely to significantly speed up the process of global warming.	Sharp increase in atmospheric methane concentration, which leads to unpredictable climatic changes.
	Pollution and Ecosystem Health Module Contamination by resistant organic matter	- Eutrophication, biotoxins, multiple ecological disturbances - The process of global warming and the rising levels of wastes products of all categories may lead to the release of toxic substances from disposal sites.	Sharp increase in air and water pollution concentration leading to biodiversity loss and population health risks.
	Floods	Increasing floods may lead to more losses in livelihood opportunities	Increasing poverty and malnutrition
Socio-ecological	Damages to the traditional lifestyle of aboriginal population	Constraints to the on-time adaptation of aboriginal communities to the ongoing changes.	Threat to traditional aboriginal population lifestyle.
	Agriculture and Health impacts	Specific climatic conditions.	Pests, droughts, food insecurity, degradation of environmental resources
		Integrated or isolated impact of natural-climatic and techno-ecological risks.	Increase in the frequency of reproductive losses.

Techno-ecological	Constant techno-genic burden	▪ During geophysical survey: hydraulic impact, noise exposure. ▪ During hydrocarbon transportation: intentional discharge of petroleum products (transportation mode - tanker); excavation and trenching in petroleum depots construction activities.	Permanent adverse impact on the ecosystems, extinction of living organisms, fresh water contamination, human losses
	Accumulated ecological damage	The effects of anthropogenic activities within aquatic ecosystems such as processing companies/enterprises, car washing points, human settlements.	Constant environmental threats in the region.

It is clear from the above summary that the region is subjected to various large-scale ecological risks which can have both long-term and short-term effects. Besides, combined with other impacts, these effects could significantly increase the threat level and impede necessary response actions. As the region has increasing high population density, the environmental safety system is of great importance. Currently, there is no emphasis on the region's environmental protection and minimization of the adverse effects of urban sprawl in the region. Unqualified human capital and, above all, high level of corruption, seem to have compromised the application of environmental rules and regulations.

Perceived Major Future Climate Change Impacts/Risks

Climate change projections for this region point to a warming trend, frequent occurrence of extreme heat events, increasing aridity and changes in rainfall. Future climate change impacts and vulnerabilities, according to projections from agricultural/environmental and health experts in the region include increase in surface air temperature, frequent floods, and increase in water demand for drinking, agricultural irrigation and losses in rain-fed agriculture, increases in endemic morbidity and mortality due to diarrheal disease primarily associated with floods and droughts, negative impact on fisheries sector (Table 8).

Table 8: Climate change impacts and consequences for food systems

Climate change impact	Direct consequences for food systems
Shifting agricultural seasons	Reduced quantity and quality of agricultural yields and forest products. Shortage of water Greater need for irrigation
Increased frequency and severity of extreme weather events	Crop failure or reduced yields Loss of livestock Damage of forests Destruction of agricultural inputs, such as seeds and tools Increased land degradation and desertification Disruption of food supply-chains Increased costs for marketing and distributing food

Global warming and a changing climate are expected to have a multitude of direct and indirect impacts, including: frequent floods; modifying the composition of land use and land suitability for food and fibre crops; shifting growing periods; increase in water demand for drinking, agricultural irrigation and losses in rain-fed agriculture; increases in endemic morbidity and mortality due to diarrheal disease primarily associated with floods and droughts, negative impact on fisheries sector. Perceived major problems and their root causes can be summarized as follows (Table 9).

Table 9: Perceived major problems and their root causes.

Perceived Major Problems	**Transboundary Elements**	**Main Root Causes**
Degradation of ecosystems	Loss of biodiversity and ecological goods and services leading to ecosystems instability Decrease in quality of life. Increased poverty Loss of revenues	1. Inadequate Management and weak Institutions 2. Extreme Poverty 3. Limited stakeholder Participation 4. Insufficient qualified human resources and Institutional Capacity
Overexploitation of valuable natural resources	Loss of natural resources productivity Loss of potential income from agriculture, fishing and tourism Increased poverty Threat to biodiversity Degradation of streams/rivers	1. Insufficient qualified human resources and Institutional Capacity 2. Inadequate Management 3. Weak Institutions 4. Extreme Poverty 5. Limited Stakeholder Participation
Soil degradation and increasing sedimentation	Economic losses due to sedimentation Increased poverty Loss of wetlands Eutrophication of water bodies and the coastal zone Loss in water storage capacity of river courses	1. Limited Stakeholder Participation 2. Insufficient qualified human resources and Institutional Capacity 3. Inadequate Management 4. Weak Institutions 5. Extreme Poverty
Pollution of water bodies	Loss of biodiversity Increased poverty Deterioration of hygienic-sanitary conditions Lack of territory identification and settlement	1. Extreme Poverty 2. Inadequate management 3. Weak institutions 4. Insufficient human and institutional capacity

High vulnerability to natural hazards	Increased poverty Human settlements in areas exposed to landslides (hill-side housing and agriculture), and flooding (riverside housing) Increase of surface runoff and flooding areas	1. Low incomes, subsistence economies and poor sanitation: relative imbalance in employment and income-generating opportunities across the border 2. Inadequate management 3. Weak institutions (Laws are not being complied; abundance of laws and regulations, but inadequate national and regional policies and institutional frameworks; inadequate access to information for decision-making).

These climate-related risks raise important concerns regarding the future sustainability and resilience of certain crops in the Bamenda highlands in general, since agriculture plays a multifunctional role in integrating natural resources management, rural development and food production and underpinning environmental heritage through the maintenance of semi-natural habitats, landscape and biodiversity. Agriculture also supports the economy for rural communities where it buffers rural poverty and enhances the social fabric of rural areas by contributing to more balanced rural land development. Climate change therefore threatens to impact significantly on both the production of food crops and the rural livelihoods which depend on them.

Environmental safety system

To prevent or mitigate the damage caused by extreme conditions, such as flooding and droughts and other effects of natural phenomena, it is necessary to set up and early warning system about possible swelling of water bodies and to monitor hydrometeorological behavior. It is also necessary to set up a seismographic network to monitor the behavior of volcanoes and tectonic faults. Similarly, social organization is necessary to design and test emergency plans for natural phenomena, to reduce the damage they cause. In this context, it is required to incorporate environmental issues into all spheres of the region's development programme forming a complex environmental safety system (Fig. 7).

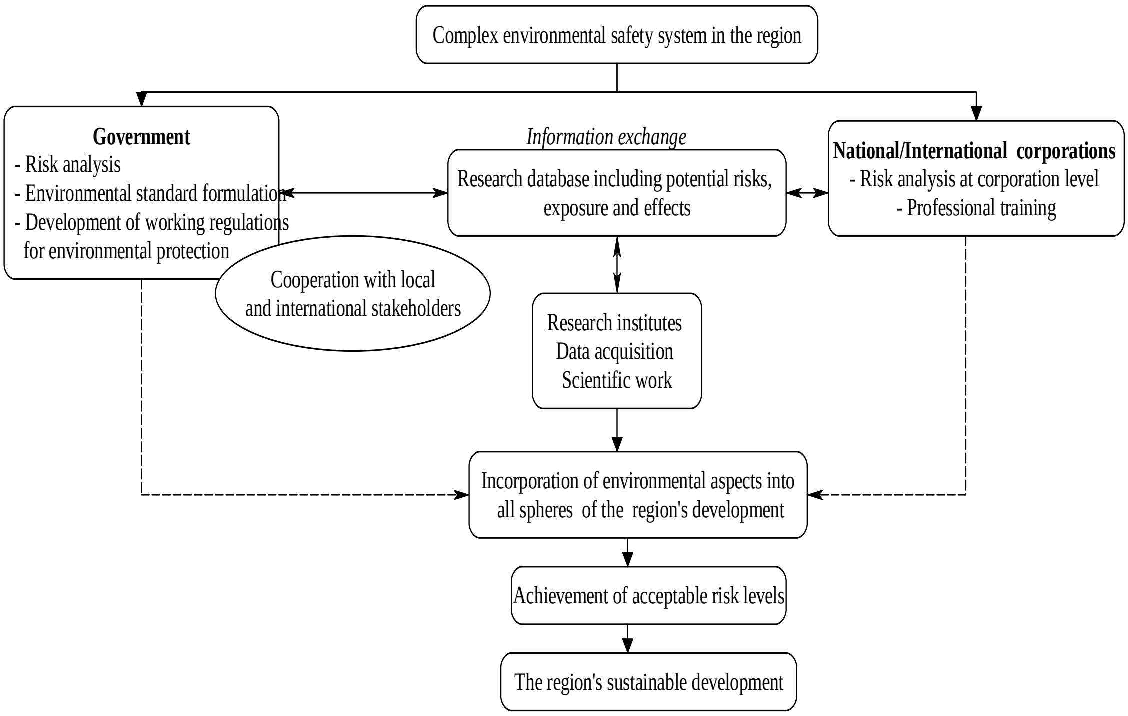

Figure 7: A complex environmental safety system for the Bamenda Highlands.

To increase the efficiency of the proposed system, the following actions should be taken:

- Creation of research database relating to potential risks, exposure and effects;
- Formulation of environmental standards which would clearly regulate the activities to be performed in the Bamenda highlands;
- Active cooperation of the government and companies in the Arctic environment protection;
- Facilitation of international cooperation in environmental safety system development including the development of uniform legal regulation criteria for the Bamenda highland's environmental protection.

In the context of reinforced international cooperation, it is necessary to consider political instability which may cause the situation to escalate and lead to tension between economic growth and environmental protection. Therefore, it is of great importance to draw the right lessons from worldwide experience and find such solutions that would be effective not only in grass fields and Cameroon in general, but within the whole of central and west Africa and the world. Institutions responsible for the control and regulation of natural resource use must be strengthened, both technically and economically, and be given the means for their mobilization. This would enable them to have a real presence in the territory. It is also necessary to create mechanisms for enforcing the current legislation. Unfortunately, due to the lack of institutional resources (institutional weakness), there is little or no community participation in decision-making relating to the use of environmental resources. Often this is not forthcoming because of the apathy of communities to these things, frequently associated with the lack of education or motivation to solve the most pressing problems, precisely because economic resources are scarce. Perhaps one of the greatest difficulties for integrated environmental safety system management is precisely the institutional weakness of the state entities in charge of natural resource management. Underfunded budgets, staff shortages, excessive workloads, etc. are some of the challenges to more effective management these institutions face. One must also mention the lack of coordination between state entities, which do not pool resources with other agencies operating in the same region. This has limited the effectiveness of state action in the region.

CONCLUSION

The research assessed the climatic risks in the Bamenda highlands of Cameroon and proposed an environmental safety system that can help mitigate these risks. Results point to significant losses and damages being a consequence of inadequate mitigation of, and adaptation to, climatic changes across the region. Based on the scale of the environmental problems revealed from the study, it is possible to conclude that the contemporary environmental safety policy can hardly guarantee sustainable development of the Bamenda highlands. The absence of systemic approach and complex ecological risk analysis impedes the development of strategies to minimize the negative impact on the environment and reduce the dependence of the region’s projects on their economic viability.

Despite increasing number of environmental protection projects, the scale of the development and production activities that is planned in region suggests a weak turn towards ecological issues. To address this issue, the complex environmental safety system which considers the negative effects of the risks not only at the stage of strategic development but also during project implementation has been developed. The risk analysis, being an integral component of the proposed system, is of great importance as it enables stakeholders to identify the definite hazard sources and predict their potential damage in order to provide the sustainable development in the region within the acceptable risk levels.

We recommend a strategic framework for climate risk mitigation in the region. The main objective of the framework will be to define a regional strategic approach to increase the resilience of the Bamenda highland ecological and socioeconomic systems to the impacts of climate change, assisting policy makers and stakeholders at all levels across the grassland area in the development and implementation of coherent and effective policies and measures by identifying strategic objectives, strategic directions and priorities that:

- Promote the right enabling environment for mainstreaming adaptation in national and local planning;
- Promote and exchange best practices and low-regret measures; promote leveraging of necessary funding; and
- Exchange and access best available data, knowledge, assessments and tools on adaptation.

There is also need for capacity building at all levels to reduce and respond to the new and exacerbated challenges that loss and damage poses, as well as coordination between agencies, organizations, and other groups. The degradation of the ecosystems makes the economic and social infrastructure of the region more vulnerable and increases the potential impact on the population. This vulnerability is reflected in shorter periods between the occurrence of floods or droughts and the soil becomes more unstable. Possible solutions to the problem of deterioration of the ecosystems include developing formal and informal environmental education programs to make farmers more aware of their actions; increasing enforcement of the existing legislation; promoting proper natural resource management; and promoting the organization of grassroots groups to control burning from the outset.

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