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RESEARCH ARTICLE

Determinants of Cocoa Productivity and Vulnerability to Climate Change in Central Cameroon: An In-Depth Analysis of Farmers' Perspectives

Chimi Djomo Cédric[1,2], Tanougong Armand Delanot[1], Joël Martin Atangana Owona[3], Serges Okala Ndzie[1], Barnabas Neba Nfornkah[1], Kevin Enongene[1], Eugene Chia Loh[1], Elsie Fobissie[1], Dieudonne Alemagi[1], Nyong Princely Awazi[1,4,*], Karol Lavoine Mezafack[1], Parfait Kamta Nkontcheu[1], Stelle Vartant Djeukam Pougom[1], Kevin Tchemmoe Fokou[1], Katty Claudia Chiteh[1], Kabelong Banoho Louis Paul Roger[5] and Kalame Fobissie[1]

[1]*FOKABS Cameroon, Cameroon*

[2]*Institute of Agricultural Research for Development, Cameroon*

[3]*The Sustainable Trade Initiative, Cameroon*

[4]*Department of Forestry and Wildlife Technology, University of Bamenda, Cameroon*

[5]*Department of Plant Biology, University of Yaoundé, Cameroon*

Abstract: This study aimed at analyzing the determinants of cocoa productivity and vulnerability to climate change in Central Cameroon. The methodological approach consisted of questionnaire administration to 152 cocoa farmers in the Ngoro municipality. Multiple generalized regression analyses were run to identify socio-demographic and management practices that significantly influenced cocoa productivity and vulnerability to climate change. Results showed that cocoa farming is done predominantly by men (97%) with cocoa farms covering an average of 5 ha (57%) and cocoa bean productivity varying between 0.08 and 15 tons per farm. It provides money in cash varying from 151 to 28,275 USD. Age of farm and household size were the socio-demographic determinants that significantly (positively) influenced cocoa productivity. Cocoa farm size, number of years spent, and clearing/bush fire management were management practices that significantly influenced cocoa productivity. Climate change was perceived by all farmers (100%) as the main factor that negatively influenced cocoa productivity. Given the monetary value associated with cocoa farming, which contributes to the local farmers' well-being and then food security, it is becoming more important than ever to ensure that the management practices in cocoa farming systems consider ecological aspects, to enable Cameroon meets its commitments in terms of food security, biodiversity conservation, and the fight against climate change.

Keywords: Cameroon, cocoa productivity, climate change, local perception, multiple generalized regression, Ngoro municipality

1. Introduction

Agroforestry is a dynamic and ecological resource management system that, through the integration of trees into farms, diversifies and sustains smallholder production for increased socio-economic and environmental benefits [1]. This system is too importance for local population livelihoods especially the rural populations around the world in both temperate and tropical regions [2]. In fact, they are a source of income to farmers due to the cash or money it provides, and several other services linked to diversification of associated trees like fruits and medicines and contribute to food security and people's well-being [3, 4]. Ecologically, agroforestry plays a key role in environmental protection including biodiversity conservation, habitat of several species, and climate change mitigation [5, 6].

Cocoa-based agroforestry systems, which are generally practiced by smallholder farmers, are widely spread in sub-Saharan Africa and particularly in Ivory Coast, Ghana, Nigeria, and Cameroon which are the main cocoa-producing countries in Africa [1, 7, 8]. In Cameroun, since the cocoa cultivation introduction around 1886, cocoa-based agroforestry systems have become the major cocoa production systems [9]. According to the Ministry in charge of Agriculture in Cameroon, cocoa cultivation has increased from 250,000 ha to about 670,000 ha in 2014 and its area continues to increase over time. In fact, projections show that within a few years there could be over

*__Corresponding author:__ Nyong Princely Awazi, FOKABS Cameroon and Department of Forestry and Wildlife Technology, University of Bamenda, Cameroon. Email: awazinyong@uniba.cm

900,000 ha of cocoa land. Cocoa represents about 19% of the total value of the country's exports, and its production is estimated at 220,000–300,000 tons of cocoa produced annually [7]. It has evolved over the last few decades and is now Cameroon's second most important source of foreign currency after hydrocarbons. It employs over 600,000 cocoa farming families, and almost 8 million people live directly or indirectly from the cocoa economy [10–12]. Despite these results, the cocoa production system faces many challenges including social and management practices determinants that need to be addressed at local, national, regional, and international levels. In fact, due to management practices and other factors, cocoa productivity is not standard for all cocoa farmers. Regarding socio-demographics and economic impacts, numerous studies show their influence on production and yields [7]. Regarding the investigations of Frederick Mbufor et al. [13] and Kenfack Essougong et al. [14], demographic factors have positive and significant impacts on technical efficiency and cocoa productivity. According to Ndo et al. [6], the management practice influences significantly the cocoa agroforestry productivity. The findings of Akoutou Mvondo et al. [1] show that the cocoa agroforest management permits to identify various structures of cocoa-based agroforestry systems, significantly influencing the cocoa production.

Regarding climate vulnerability aspect, cocoa is one of the plants highly sensitive to changes in climate. Several studies have shown the influence of climate on cocoa production [15, 16]. Wang and Yapo [17] find a positive effect of climate change on cocoa productivity in Nigeria and Ivory Coast, respectively. In fact, they find a combination of optimal temperature and minimal rainfall in their study area that correspond to best conditions required by cocoa for optimal growth and improved production. Yakan et al. [7] report that changes in crop productivity are the result of a changing climate and any human management response in relation with mitigation such as increasing fertilizer or water use or adoption of new crop varieties.

Weather elements can also alter stages and rate of development of cocoa, pests, and pathogen, modify host resistance, and result in changes in the physiology of host pathogens/pest interaction [15]. The most likely consequences are shift in the geographical distribution of host and pathogens/pests alter crop (cocoa) productivity and crop losses which will impact on socio-economic variables such as farm income, livelihood, and farm-level decision-making. It is in this context that the current study focused on Ngoro Municipality that is one municipality where cocoa activities occupy a pride of place for local people. The aim of this study was to identify the factors that influence the cocoa bean productivity and the effect of climate change on cocoa-based agroforestry system.

2. Materials and Methods

2.1. Study site

The current study was carried out in the Municipality of Ngoro belonging to the Division of Mbam and Kim, Centre Region of Cameroon. It is situated between 11°10 and 11°30 E and 4°40 and 5°20 N at approximately 160 km from Yaoundé the political capital of Cameroon and covers a total area of 1576 km^2 (Figure 1). The relief of this study area is not very uneven, and it is characterized by plains and gentle slopes. The altitude varied between 400 and 600 m. The climate of this study area is a sub-equatorial Guinean climate characterized by four seasons: a short rainy season (March to June) and a long rainy season (mid-August to October): a short dry season (June to mid-August) and a long dry season (October to March). The average rainfall is around 1100 mm, and the average annual temperature varies between 23°C to 27°C [18]. The soil is characterized by a ferralitic texture and has affinities with brown soils; hydromorphic soils are found along the rivers. The municipality of Ngoro is drained by a multitude of rivers, the most important of which are tributary to each other, include: the Pem River in the North, at the boundary with the municipality of Yoko, the Djim River in the East at the boundary with Mbangassina and the Mbam River [18]. According to Letouzey [19], this study area belongs to a forest-savannah transition zone with savannahs dominated by species such as *Pennisetum purpureum*, *Hyparhenya rufa*, *Chromolaena odorata*, *Mimosa* sp., and grasses as well as swamp areas dominated by Maranthaceae and Zinziberaceae. Plant species such as the *Musanga cercropiodes*, *Eupatorium* sp., and *Chromolaena Odorata* cover the land left fallow [18]. Agriculture, which is mostly focused on cocoa, yam, cassava, banana, macabo, etc., represents the main activities of local people of Ngoro. However, Ngoro is one of the main production basins of cocoa in the Centre Region of Cameroon [18].

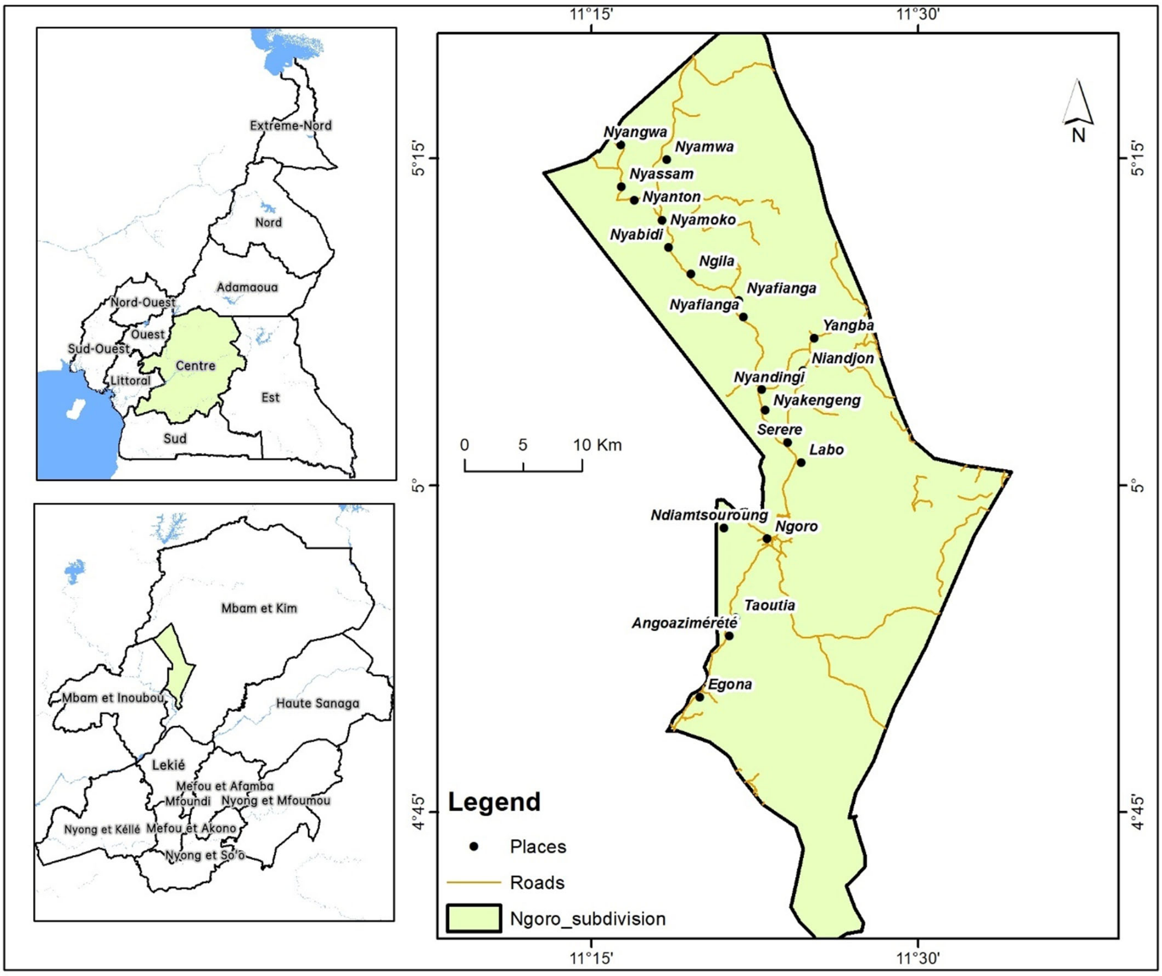
2.2. Data collection

Data collection was carried out in 12 of the 24 villages in the municipality. These villages were selected or chosen with the help of the administrative authorities in charge of agriculture (MINADER), the Municipal Council of Ngoro, some NGOs leaders and patterns involved in cocoa activities in the municipality of Ngoro through a workshop. These were the main villages where cocoa activities were significantly carried out by local farmers. Then, the methodological approach was based on the administration of questionnaires to cocoa local farmers using a stratified random sampling method. For that, the study area was divided into 3 stratums to be sure to have a sampling that is representative of all the municipality. In each target village, household sample were identified using the snowball principle. In this sense, only people who have at least one cocoa plantation were considered in our sampling and our questionnaire was administered. Thus, a total of 152 respondents were surveyed. The questionnaire administration was done face to face near each respondent and the main questions focused on socio-demographic and economic profile of each, cocoa plantation activities including cocoa farm management practices, yield and incomes of cocoa, impact of climate change on cocoa productivity, and adaptative strategy.

2.3. Data analysis

Data analysis was done through the software R (version 4.1.1). They were focused on descriptive analysis and multiple regression analyses (MRA). MRA were used to appreciate the determinant factors that have a significant influence on cocoa productivity. For that reason, the response variable (quantitative) was cocoa bean yield and mixed predictive variables that included qualitative and quantitative variables, where firstly the socio-demographics parameters like sex, age of farm, education, ethnic groups, and number of persons in the households, and secondly, parameters related to management practices like cocoa farm area (ha), types of agricultural system (mixed or monoculture), distance between cocoa farm and village, type of labor and management practices (clearing, use of phytosanitary drugs, wildfire). The significance of a parameter was observed at 95% confidence interval (significant for $p < 0.05$; and non-significant for $p > 0.05$).

Figure 1
Geographical location of Ngoro Municipality



3. Results and Discussion

3.1. Results

3.1.1. Socio-demographic and economic profile of respondents

A total of 152 respondents were surveyed, they were mostly men (97%), and women represented only 3%. Their ages ranged from 15 to more than 45 years old. Those of +45 years represented 49%, 35–45, 25–35, and 15–25 represented respectively 27, 19, and 5%. Almost 55% of the surveyed population had less than or equal to secondary education, 43% had primary education, and 2% had been to university. The natives represented 84% of the zone, and 16% were aliens who have migrated into the study area, especially in search of agricultural land. Concerning ethnic groups, the Sanaga and Djanti were represented each by 33%, Baveck represented 10%, Yambassa 7%, Mambila and Bamiléké each represented 1% and Nyanson and Bafia who were represented by one person each represented less than 1%. The number of people in the household was in most cases above 4 (representing 77% of respondents), and only 23% of the persons varied between 1 to 4 people in the household.

From an economic point of view, agriculture was the main productive activity with 98% of respondents. Other activities represented 2% of the respondents and constituted livestock, trade, gathering NTFP, fishing, and hunting and represented the sources of income for these households. Most households surveyed have an average monthly income range of 42 USD to 83 USD per month, which represented 26%; 20% with an average monthly income of less than 42 USD. Only 5% of respondents have an average monthly income of more than 250 USD (Figure 2).

Figure 2
Average monthly income per household of cocoa farmers in Ngoro municipality

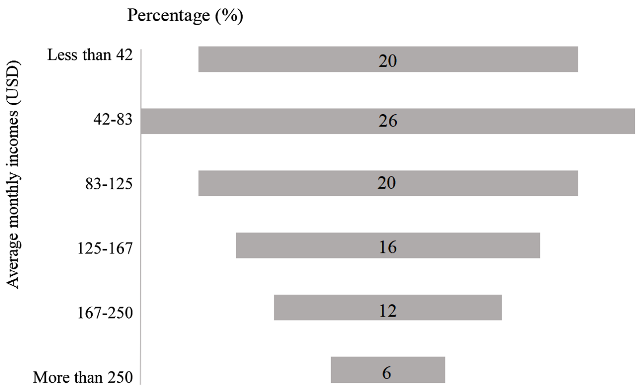
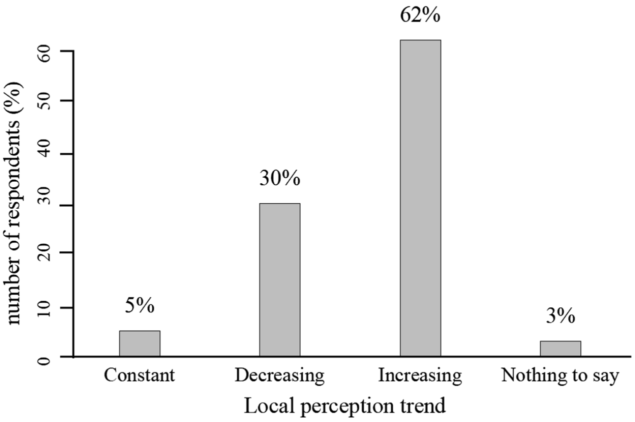


Figure 3
Local cocoa farmers' perception on the trend of productivity over time in Ngoro municipality



3.1.2. Cocoa farmers in Ngoro municipality

According to this survey, the average farmer area under cocoa farming is 3.4 ha. Many (57%) have above 5 ha, 17, 40, and 5% have respectively 3–5 ha, 1–3 ha and less than 1 ha. For 62% of respondents, the total area covered by cocoa farms has increased (Figure 3). Despite that, 96% of households plan to increase the area of their cocoa plantation. 38% opted to increase more than 5 ha of their cocoa farm soon, 26% opted to increase from 3 to 5 ha, 31% opted for 1–3 ha, and only 5% opted for less than 1 ha. In general, the range number of ha farmers wish to increase is 0.5–100, with a mean 5.7 ha, with a standard deviation of 9.25 ha. These plantations were mostly (40%) situated at 3–5 km from the villages or homes, for 39% their farms were at more than 5 km; for 19%, theirs were between 1 and 3 km. With the diversity of landscape in Ngoro municipality, local people plant cocoa plants in forest landscape (85%), savannah grassland (10%), and woody savannah (5%). The choice of forest landscape was especially due to the cocoa variety which are ordinary/traditional variety (76% of respondents) and shade provided by conserving trees in farms will help cocoa plants grow easily. Concerning cocoa farm ownership, many inherited farms (43%); 40% created farms; 10% bought farms, and 8% got farms as gifts. However, many (26%) carried out cocoa farming in an open system and the cocoa varieties were improved varieties that need sunlight to develop better and were encouraged in the savannah landscape. About 56% of cocoa farmers have already spent more than 10 years in the coca farming business, 35% have spent 5–10 years, 9% spent less than 5 years.

3.1.3. Cocoa productivity and incomes

For the previous years, the quantity of cocoa bean produced varied from 0.08 to 15 tons with respect to the producer with an average of 1.32 tons. The average price of a kilogram of dry cocoa bean was 1.9 USD as mentioned by cocoa farmers in the study area in the previous years. In this case, the total income of cocoa bean varied from 42 to 28,275 USD with an average of 2,487 USD. When extrapolated with the 148 cocoa farmers who provide information concerning the total yield of their cocoa farm, gives 243.94 tons of cocoa bean produced in total on an estimated surface area of 305.5 ha. The total income provided is estimated at 463,486 USD. It is noted that in the context of this study 600 XFA = 1 USD.

3.1.4. Socio-demographics and management practices determinants influencing cocoa productivity

Multiple generalized regression was used to assess the influence of socio-economic and management proactive on cocoa productivity. Considering socio-demographic parameters, it was noticed that only age of farmers and number of persons in the households have a positive and significant ($p < 0.05$) influence on the cocoa productivity estimated in tons. Other parameters influenced the cocoa productivity, but their influences were not significant ($p > 0.05$). Considering management practices by farms, it was found that cocoa farm area (ha) and number of years spent in cocoa cultivation have a significant positive impact on the productivity of cocoa beans; nevertheless, these management practices included clearing and wildfire having a significant negative impact on cocoa productivity of bean (Table 1).

3.1.5. Perception of the effects of climate change on cocoa productivity in the Ngoro Municipality

According to local farmer's perceptions, climate change was perceptive in the Ngoro municipality by all the farmers interviewed (100%). Regarding climate change trends over the past, 91% of respondents opined that it was characterized by an increase of temperature and drought (6%). Nevertheless, 3% thought that over the past, temperature has decreased. Concerning precipitations, many local farmers mentioned that it was characterized by rainfall decrease (60%), late rainfall (17%), and early interruption of rainfall (9%). However, 13% perceived that rainfall has increased over time.

Of the 141 persons who responded on the impact of climate change on cocoa productivity, 96% confirmed the impact of climate change on cocoa productivity. Climate variability (36%), forest deforestation/degradation (21%), and wildfire (4%) were identified as the main phenomena that negatively influenced the cocoa productivity in Ngoro municipality. Other factors representing phenomena were the presence of mounts and conflicts with other local people. Many local people (69%) perceived that cocoa productivity decrease was the main consequences of climate change. For 20 and 6%, who mentioned consequences of climate variability like the dying off of cocoa trees and increase harmful insects to cocoa plants; and others (5%) like the invasive species that colonize the cocoa farm, cocoa plant disease increasing as well as the rot of fruits (Figure 4). Part of management practices put in place by farmers to face the reduction in cocoa productivity caused by the changing climate include increasing of cocoa land, clearing, phytosanitary treatment and replacement of dead cocoa plants with new cocoa seedlings.

3.2. Discussion

3.2.1. Overview on cocoa productivity in the Ngoro Municipality

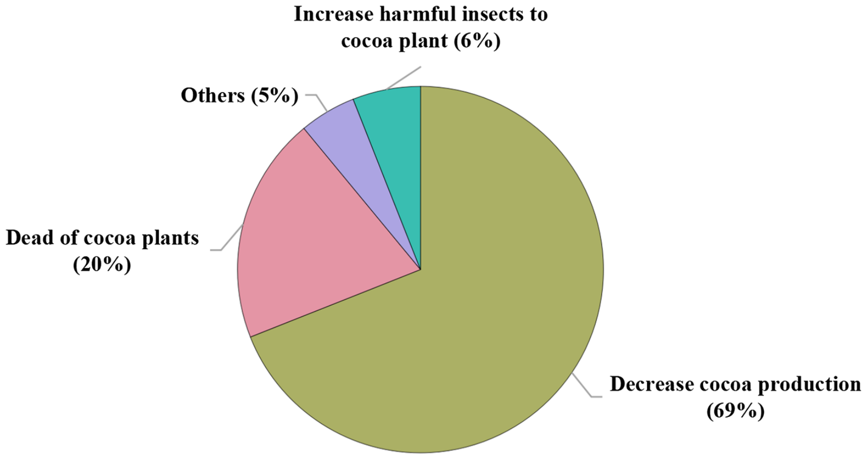
The Centre Region of Cameroon is one of the main cocoa basin of Cameroon [6]. In this paper, investigation done in Ngoro municipality has permitted to confirm that cocoa cultivation is the principal activity of local people and for which it provides incomes that they need for their subsistence [18]. Nadege et al. [20] mention the importance of cocoa agroforest in local people's livelihoods in the Centre Region of Cameroon. Findings of this study showed that cocoa cultivation is mostly done by men and women are disadvantaged. In fact, Boutillier et al. [11] record that women are highly disfavored with regard to cocoa land occupation and certain cultures sometimes do not allow them to own land, and as such, access to land is limited;

Table 1
Multiple generalized regression for cocoa productivity/board bean in function of some socio-demography and cocoa farm management parameters

Parameters		Estimate	Std error	*t* value	Pr(>|t|)
Socio-demographics	(Intercept)	−3.299	3.016	−1.094	0.276
	Sex [Men]	1.637	1.928	0.849	0.397
	Sex [Female]	0.552	2.235	0.247	0.805
	Age of farmers	**0.056**	**0.020**	**2.863**	**0.005****
	Education [Primary]	−1.080	1.992	−0.542	0.589
	Education [Secondary]	−1.257	1.971	−0.638	0.525
	Education [High]	−1.256	2.266	−0.554	0.580
	Ethnic group [Voute]	1.834	1.267	1.447	0.150
	Ethnic group [Manguissa]	0.627	1.764	0.355	0.723
	Ethnic group [Anglophone]	0.656	1.751	0.374	0.709
	Ethnic group [Others]	1.681	1.120	1.502	0.136
	Number of persons in the household	**0.850**	**0.417**	**2.040**	**0.043***
Management practices	(Intercept)	−0.970	1.050	−0.924	0.357
	Cocoa farm area (ha)	**0.384**	**0.049**	**7.854**	**0.000*****
	Type of agricultural system	0.494	0.495	0.998	0.320
	Distance between cocoa farm and village	0.143	0.139	1.028	0.306
	Number of years spent in cocoa farming	**0.136**	**0.070**	**1.952**	**0.043***
	Type of labor[family]	−0.781	0.982	−0.796	0.428
	Type of labor[workmen]	−0.843	1.008	−0.837	0.404
	Management practice [clearing and phytosanitary products used]	−0.787	1.522	−0.517	0.606
	Management practices [clearing and wildfire]	**−0.983**	**0.554**	**−1.775**	**0.048***
	Management practice [clearing and others]	−0.796	1.081	−0.736	0.463

Notes: Socio-demographic model: Residual deviance = 476; AIC = 604; Dispersion parameter = 3.634; management practices: Residual deviance = 301; AIC = 527; Dispersion parameter = 2.285.
The statistical analyses are significant at a 95% confidence interval. ***$p < 0.001$ **$p < 0.01$; *$p < 0.05$; and nothing $p > 0.05$ (non-significant).

Figure 4
Effects of climate change on cocoa productivity in the Ngoro Municipality



it was in accordance with those found in this study. Concerning age of cocoa farmers, they were more of people of above 45 years old. The absence of youths in the cocoa farming could be linked to rural exodus, as many leave the villages in search for greener pastures in the cities. Also, many youths in the villages prefer to joint motor taxi business (bike riders). They believe this provides them with easier cash for their subsistence. For the few left in the villages, they are gradually being injected into the cocoa farming business, partly because the cocoa price has seen some increase in the last decade [15]. Many youths begin with inherited farms, harvesting from very old farms, before looking forward for rejuvenating them and adding new farms. With the need to have much money, younger cocoa farmers were identified as those who show the more desire to increase the area cultivated over the years with the basic objective of increasing their income and for their physical ability to cultivate more land than older farmers. On the other hand, cocoa farmers prefer to establish their plantations in forest areas because of cultural heritage, the desire to farm in association with trees, and the difficulty of growing cocoa in savannah in their context. In addition, many cocoa farms are done in an open system because the cocoa varieties used are those that need sunlight to develop better. In this case, cocoa farming is one of the cause of deforestation in Ngoro municipality.

Looking at cocoa an economic point of view, the weak income due to commercialization of cocoa bean despite the quantities produced is explained by the fact that Cocoa farmers in Cameroon do not determine the price of cocoa in general. It is determined by the Cocoa and Coffee National Board (ONCC) in collaboration with the Ministry of Trade. The prices of cocoa fluctuating over time and those who come to buy cocoa bean in the village (*Coxeurs or middlemen* and legal buyers) do not apply the homologated prices, and in this sense, it is a disadvantage for cocoa farmers. Income provided by cocoa farming helps them earn money to meet up with their family needs [2, 20].

3.2.2. Determinants of cocoa productivity

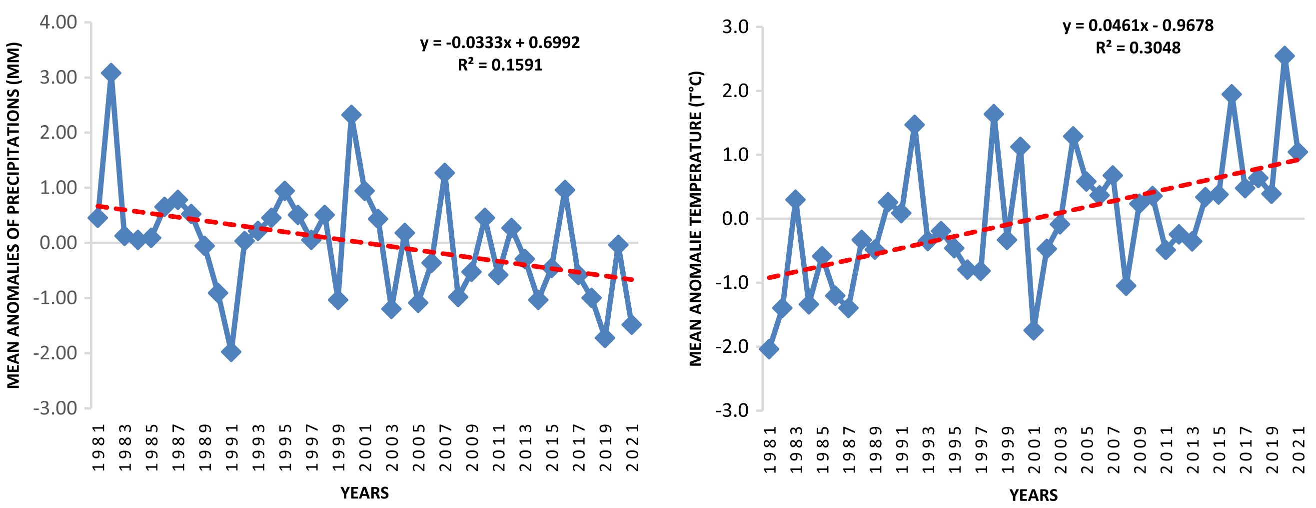
Socio-demographic characteristics have influenced on cocoa productivity [2, 21]. More especially, the age of the farmer had a positive and significant effect on cocoa bean productivity. Indeed, in accordance with the study of Yakan et al. [7] and Ndo et al. [6] one might think that the older a farmer is, the more experience he has in managing his cocoa farm (a management parameter that also has a significant influence on productivity), and consequently, the productivity from his cocoa farm can only be good. However, in addition to this determinant of cocoa yield, the number of people in the household also had a significant and positive influence on productivity [7]. This could be explained by the fact that the greater the number of people in the household, the greater the amount of family labor required to maintain the cocoa farm, and the better the cocoa farm is managed in time, and consequently, cocoa productivity increases [15]. Several years of experiences of cocoa farmer management practices are also characterized by diversification of income sources and crops, efficient use of land and labor, risk avoidance, and use of environmentally friendly farming methods [3]. At the same time, the management method involving manual weeding and bush fires has had a significantly negative impact on productivity, as cocoa trees are very sensitive to bush fires, as mentioned by certain cocoa farms during fieldwork. It has been shown that bush fires are a factor that contributes to the reduction in cocoa farm productivity. However, overgrowing is widely practiced in the study area and the fires that are generally found in cocoa farms come from the fields. Regarding the total area of each farmer's cocoa farm, it is theoretically clear that the greater the area used for cocoa productivity, the higher the yield should be and then incomes will be increase. It was observed that some of the farmers with large farms had not enough capacity (fund) to manage them, resulting to productivity not commensurate to the farm surface area. Meanwhile, farmers with relatively small farmlands (1–3 ha) were able to provide labor and afford phytosanitary treatments, thus increasing cocoa productivity per ha.

It was also found that phytosanitary used to treat cocoa plant has positively influenced the cocoa yield. In the case of this study, even a positive influence was found, but it was not significant. This can be explained by the fact that the use of conventional pest control methods are no longer successful because pests/pathogens have developed resistance/adaptive mechanisms over time [16]; consequently, cocoa farm become less resistant to diseases despite phytosanitary treatment. On the other hand, soil quality could be one of the parameters which can significantly influence cocoa productivity [22]. However, we did not consider this parameter in the study.

3.2.3. Climate change impact on cocoa yield in Ngoro

As reported by Oyekale [15], climate change was perceived by local people as the most negative impact on cocoa productivity. In Ngoro municipality, this finding was confirmed by the past trend of climate variability observed in this area. In fact, with the analysis of climatic data obtained from NASA [23] in the last 40 last years (1981–2021), anomaly regression showed that mean temperatures have increased, and precipitation has decreased, as shown in Figure 5 [22]. These climatic changes affect plant growth and productivity through the spread of pests and diseases for which they increasingly develop resistance to phytosanitary used and then attack and cause cocoa plant dead [22]. Other expected consequences included the increase exposure to heat-related stressors. This can justify the drought effect mentioned by local respondents affecting the long-term effect of a drop in cocoa yield and then affects the welfare of the cocoa farmers. Frederick Mbufor et al. [13] record the same results in Meme Division situated in the South-west region of Cameroon. In fact, with temperature increase and precipitation decrease, the best growing conditions of cocoa

Figure 5
Anomalies of precipitations and temperature in Ngoro municipality



plants are perturbed, and then, the cocoa productivity is decreasing, and finally, cocoa income is decreasing. These local farmers mentioned the increasing of cocoa plant attack by various parasites and caterpillars due to climate variability [16] and the conventional cocoa farm treatment becomes less effective.

This is contrary to the study of Ojo and Sadiq [24], who mention that climate change has a positive impact on cocoa yield. In fact, according to the period that their study was done, climate was favorable with cocoa cultivation because they found a combination of optimal temperature and minimal rainfall respectively 29°C and 1000 mm will improve farmers cocoa productivity in Nigeria. In fact, based on climatic condition point of view for an optimal cocoa yield productivity, average temperatures, and precipitation, the optimal annual temperature will be around 25°C, and those of precipitation will be around 1200 mm. It is important to note that excess of rain contributes rather to cocoa productivity decreasing [15].

With global climate change that is a reality, cocoa farmers develop and implement resilience strategies especially in management practices [15, 17]. In Ngoro Municipality for example, farmers (98%) expressed wish for the expansion of cocoa. For others, they are more focused on management practices like changing phytosanitary products used to fight against pest/pathogen and replace dead cocoa trees using hybrid seeds of cocoa.

3.2.4. Implication of Ngoro cocoa plantation in policy

As an agricultural activity, cocoa plantations have always been identified as a factor in forest degradation and fragmented natural landscapes [9, 25]. In the municipality of Ngoro, forest degradation is historically linked to agriculture and cocoa cultivation expansion [18], also, observing the fact that many respondents expressed the wish of expanding their cocoa farms by an average of 2 ha/year, with a strong need to increase cocoa income. However, this activity contributes enormously to the well-being of the populations, given the cash or money they obtain from the sale of cocoa beans. Despite the forest degradation, this cocoa cultivation could help to maintain some ecosystem services [20]. In fact, cocoa-based agroforestry systems that combine indigenous associated species with cocoa play an important role in conserving biodiversity [26]. In the municipality of Ngoro, it was found that 86% of local people set up their cocoa farms in the forest landscape or selectively felling trees was done, thereby conserving trees of interest (sources of NTFPs, shade, soil fertility), many of which were threatened according to the IUCN red list [3]. It is the case, for example, of *Afzelia africana* and *Garcinia kola*, which are endogenous and vulnerable (according to RED list of IUCN) species and that were identified in cocoa agroforestry by Yakan et al. [7] near the study area where this study was carried out and belonging to the same phytogeographical area. In the same line, Akoutou Mvondo et al. [1, 27] show that cocoa agroforest management impacts on forest cover. In fact, small plantations without shade destroy 80–90% of the forest cover, whereas small plantations with shade retain 70–80% of the trees. The trees retained are mainly fruit trees (avocado, mango, NTFPs (djansang and wild mango). Finally, it can be concluded that best management practices contribute to the conservation of biodiversity and therefore to the achievement of the conservation objectives (CBD) for which Cameroon is one of the States that have ratified it.

Recognition of the immense role play by forest landscapes in mitigating climate change was established with the adoption in 1992 of the United Nations Framework Convention on Climate Change and later in 1997 with the Kyoto Protocol, the Clean Development Mechanism (CDM), the Conferences of the Parties, and more recently REDD+ [28]. At the end of these conferences, the signatories committed to stabilizing GHG concentrations in the atmosphere at a level that prevents any significant disruption of the climate, while placing particular emphasis on the central role of ecosystems in this low-cost climate regulation [29]. In this sense, cocoa-based agroforest, despite their anthropogenic nature, has been recognized as landscapes that make a major contribution to carbon storage and thus in reducing the effects of climate change [3]. As Cameroon is one of the signatory states of REDD+, the cocoa plantations in the municipality of Ngoro could be included in the framework of voluntary carbon markets and ecosystem services payments so that the ecological services provided by their plantations can be compensated for, thereby improving their income. This is therefore necessary to contractually agree on zero deforestation productivity conditions when promoting this crop.

4. Conclusion

With the aim of this study focusing on the determinants of cocoa productivity and vulnerability to climate change in Central Cameroon, it was found that cocoa farming is done predominantly by men (97%) for which 57% of them have a cocoa farm covering more than 5 ha and productivity is estimated at 0.08–15 tons per farm. We also found that cocoa productivity is influenced significantly by some socio-demographic factors (age of farm and household size) and management practices (cocoa farm size, number of years spent, and clearing/bush fire management). Nevertheless, climate change that is perceived by all cocoa farmers was one the most prominent factors that negatively impacts cocoa productivity as it contributes to the reduction of cocoa productivity by triggering the death of cocoa plants and an increase in cocoa diseases. Ngoro, as an area par excellence in better farming income derived from cocoa trade, experiences increasing deforestation due to the increasing cocoa farm sizes. However, adaptive measures to surmount the impacts of climate change by cocoa farmers in the Ngoro municipality have mainly been increase in farm sizes which increases forest degradation. This poor adaptative measure is mainly caused by the lack of knowledge and resources to invest in good agricultural practices to improve productivity. As such, concrete measures need to be taken to promote best management practices that enhance ecological services and high cocoa productivity while improving the well-being of local communities through the increasing sale of better quality cocoa bean.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

Data Availability Statement

The data used for this study are available and will be provided upon reasonable request by FOKABS Canada and Cameroon.

Author Contribution Statement

Chimi Djomo Cédric: Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Resources, Writing – original draft, Writing – review & editing, Visualization. **Tanougong Armand Delanot:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Writing – review & editing. **Joël Martin Atangana Owona:** Methodology, Resources, Funding acquisition. **Serges Okala Ndzie:** Conceptualization, Investigation, Data curation, Writing – review & editing. **Barnabas Neba Nfornkah:** Conceptualization, Investigation, Data curation, Writing – review & editing. **Kevin Enongene:** Methodology, Investigation, Data curation, Writing – review & editing, Supervision, Funding acquisition. **Eugene Chia Loh:** Methodology. **Elsie Fobissie:** Investigation, Data curation. **Dieudonne Alemagi:** Methodology, Investigation, Writing – review & editing. **Nyong Princely Awazi:** Conceptualization, Writing – review & editing. **Karol Lavoine Mezafack:** Methodology, Investigation, Data curation, Writing – review & editing. **Parfait Kamta Nkontcheu:** Investigation, Data curation, Writing – review & editing. **Stelle Vartant Djeukam Pougom:** Investigation, Data curation, Writing – review & editing. **Kevin Tchemmoe Fokou:** Software, Validation, Formal analysis, Data curation, Writing – review & editing. **Katty Claudia Chiteh:** Project administration. **Kabelong Banoho Louis Paul Roger:** Writing – review & editing. **Kalame Fobissie:** Resources, Supervision, Project administration, Funding acquisition.

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