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Review

A Review of Climate Change and Agro-industrial Development in Cameroon

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Abstract: Climate change influences the performance of Cameroon's agribusinesses. Therefore, Cameroon was considered one of the countries most exposed to climate risks. The most vulnerable sector of its economy remains agriculture, which provides raw materials essential to the development of agribusinesses. This paper addressed the issue of climate change and its influences on the development of the country's agribusiness. The methodological approach was based on bibliometric and bibliographic analyses, with a critical reading of articles published between 2005 and 2020 using search engines such as Microsoft Academic, Web of Science, Scopus, Google Scholar, and ResearchGate. The results of the literature review showed that climate change is a serious threat to the development of Cameroon's agro-industries. Observations revealed variability in rainfall and temperature and an increase in extreme weather events. Climate variability would then lead to a 15% reduction in crop yields, on average, in sub-Saharan Africa in general by 2046 to 2055 compared to 1996 to 2005. From 2005 to 2020, the number of scientific publications in the field of climate change amounted to 215,470, including 127,379 on climate change and agribusiness. The yield reduction shows that climate change is a serious threat to agribusiness development, and the number of scientific publications shows a growing interest in this issue. Mitigation measures focused on the development of both climate monitoring tools and resilience strategies.

***Keywords*:** climate change, yields, agribusiness, development, resilience, Cameroon

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) defined climate change as any change in the climate over time caused either by natural variability or human activity. It is manifested by an increase in each of the average land surface temperature, precipitation, sea level, and the frequency and intensity of extreme events (droughts, floods, cyclones) [1]. Observations since 1950 show changes in some extremes, and the confidence in observed trends in daily temperature extremes in Africa and South America generally varies from low to medium depending on the region [2]. Africa will be more exposed to these climate risks [3], and the agricultural sector, which plays a major role in the development of agro-industries, is sensitive to climate variations. This is an implacable fact that makes agriculture and agribusiness essential vectors not only to respond to the problems of food security or the fight against poverty,

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particularly in rural areas, but also to serve as a lever for more sustainable development [4]. In 2009, countries of the Central African sub-region, namely Cameroon, the Central African Republic, Congo, Gabon, Equatorial Guinea, and Chad, decided in their Regional Economic Program (REP) to make the Central African Economic and Monetary Community (CEMAC) an emerging integrated economic area by 2025. Then, the choice of agriculture and agribusiness as the driving forces of the economies was justified by the agricultural potential of the sub-region [5]. However, climate variations have an impact on agricultural development, livestock, fisheries, human health, food security, migration, and poverty [6]. Climate change, including the increase in the frequency and intensity of extreme events, has had a negative impact on food security and terrestrial ecosystems due to desertification and land degradation in many regions [7]. Climate change can influence the performance of companies, especially those whose raw materials come from climate-dependent agriculture. Today, it is one of the threats to agricultural development [8]. Many scientific studies conclude that anthropogenic climate change and its various effects constitute a major threat to human societies. The majority of scientists agree that developing countries and small island states are the most vulnerable to climate change, but developed countries will not be spared [9]. In 2009, the "Cameroon - Vision 2035" described a series of steps that could make Cameroon an emerging country by 2035. The vision provides Cameroon with an ideal frame of reference to guide its economic and industrial policy. It encourages the industrial sector to increase production, with a view to marketing locally and exporting, in order to enable the country to become an industrialized country. As part of the operationalization of this vision, the Strategy Document for Growth and Employment (DSCE) was developed, which constituted a ten-year planning framework for the period between 2010 and 2020, based on five development challenges: (i) the challenge of national unity and democratization; (ii) the demographic challenge; (iii) the challenge of economic growth and employment; (iv) the challenge of urban development and land use planning; and (v) the challenge of governance.

The ambition would be to put in place a set of conditions necessary for the implementation of a reliable, sustainable, and achievable industrial policy, thus making Cameroon a "driver of the New Industrial Africa" [10]. Unfortunately, climate change mitigation initiatives are not clearly stated. More recently, the development of agro-industries has become a subject of greater interest in Cameroon. Thus, for the period between 2020 and 2030, Cameroon aims to increase the quantity and quality of agricultural products in order to ensure food self-sufficiency, satisfy the growing demand of national agro-industries for agricultural raw materials, and conquer international markets, particularly in the Economic Community of Central African States (CEEAC) and Economic Community of West African States (CEDEAO) sub-regions [11].

According to Boko et al. [12], climate will be one of the major determinants of day-to-day economic development in Africa, particularly in the agriculture and water sectors. In Cameroon, for example, it appears that a 15% increase in rainfall by 2100 would be likely to reduce saltwater inflows into the Wouri estuary.

Simulations conducted using CMIP5 climate models to assess the robustness of projected impacts on sorghum crop yields found an average warming of +2.8 °C from 2031 to 2060, compared to the 1961 to 1990 baseline. A robust change in precipitation in West Africa is also observed, with less rainfall in the western Sahel (Senegal, Southwestern Mali) and more rainfall in the central Sahel (Burkina Faso, Southwestern Niger) [13]. The direct consequence of these climate changes would be a decrease in average crop yields of about 16 to 20%. However, CO_2 and soil fertilization could significantly offset these negative impacts on sorghum yields by about 10%, with the driest regions benefiting the most, although the net impacts of climate change remain negative even after CO_2 is considered.

Through simulations with the SARRA-H crop model by Sultan et al. [14], it was shown that the sub-Saharan region of West Africa remains highly vulnerable to climate variability events, and that the impact of climate change therefore negatively influences the yield of sorghum, millet, rice, and oil palm crops. It appears from these simulations that high temperatures significantly reduce crop yields, independent of rainfall changes, and that the increase in temperature cannot be countered by any change in rainfall. The simulations also showed that crop yields are more sensitive to changes in temperature and precipitation; and that traditional photoperiod-sensitive millet and sorghum cultivars, used by local farmers for centuries, appear to be more resilient to future climate conditions than modern cultivars selected for their high yield potential (40% yield reduction) over a 4 °C increase in temperature and a 20% drop in rainfall (Figure 1).

According to Roudier et al. [15], the negative effects of climate change on crop productivity would become increasingly severe as warming intensifies, followed by a median yield loss of nearly 15% with the most intense warming, underscoring the importance of implementing a global warming mitigation policy. However, the negative impact of climate change would be primarily due to temperature, which climate simulation models predict will increase much more than precipitation. Simulation results also showed that the effect of carbon fertilization of soils could have a positive effect on crop yields, and this effect would be particularly significant under a high carbon dioxide (CO_2) scenario for soybeans and cassava, while for maize, millet, and sorghum crops, this positive effect would be less significant. In the study conducted by Rezaei et al. [16] in West Africa, a yield decrement of 11 to 62% due to climate change was observed. The crop yields in the combined crop residue treatment with fertilizer addition were also higher than crop yields in the no fertilizer addition treatment. It is recommended that fertilization and other crop yield-limiting factors be integrated into the crop impact assessment phase to better manage crop adaptation to climate change. According to Yumkella et al. [17], the effects of climate change are likely to increase the dependence of many African countries on imports for some of their staple foods. These effects may also increase pressure on agricultural research systems to develop more heat and drought-tolerant varieties. In 2006, climatic variability in sub-Saharan Africa led South Africa to commercially grow genetically modified crops in response to the food crisis [18].

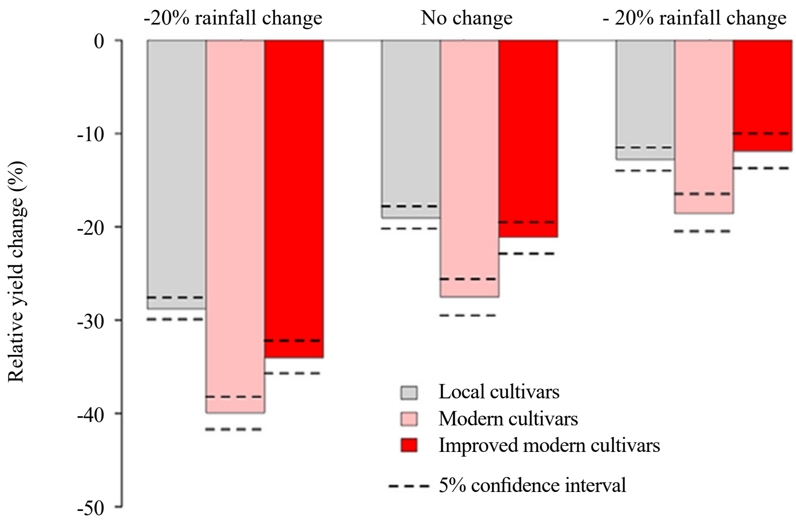


Figure 1. Mean yield change for +4 °C warming. Relative yield change (%) for three types of cultivars under a +4 °C warming and three rainfall scenarios: Local photoperiod-sensitive cultivars (two varieties of sorghum and two varieties of millet), modern photoperiod-insensitive cultivars (one variety of sorghum and one variety of millet) and improved photoperiod-insensitive modern cultivars (one variety of sorghum and one variety of millet) with higher thermal time requirements [14]

According to Challinor et al. [19], Africa is considered the most vulnerable to the effects of climate variability and change because of its high dependence on climate-dependent agriculture, which plays a major role in supporting rural livelihoods and economic growth. In Cameroon, observations made by the Ministry of the Environment, Nature Protection and Sustainable Development (MINEPDED) et al. [20] show a decrease of 2.2% per decade in rainfall since 1960 in the Highlands and Sudano-Sahelian agro-ecological zones. They also reveal a 0.7 °C increase in average annual temperature between 1960 and 2007 in the Bimodal rain forest and Guinean high savannah agro-ecological zones, as well as an increase in extreme events across the country.

Cotton production in West and Central Africa appears to be influenced by adequate rainfall (a minimum rainfall of 600 mm) and warm temperatures (around 30 °C), mainly concentrated in the Sudano-Sahelian region. According to Ton et al. [21], Burkina Faso is the largest cotton producer, followed by Benin, Mali, Côte d'Ivoire, and Cameroon. Average annual rainfall is estimated at between 700 and 1,200 mm in the growing regions of Cameroon. However, cotton production in the humid agro-ecological zones of the southern regions is still possible, but yields will be reduced due to low sunlight and a higher pest prevalence. On the other hand, West and Central Africa have distinct dry seasons that support the cultivation of high-quality cotton. Yields are highly dependent on the sowing date because the rainy season lasts only four to five months (May or June to September or October). Dry spells as well as waterlogging during the rainy season can have a significant impact on yields. An increase in the frequency and intensity of extreme events, such as droughts and floods, will negatively affect crop yields.

The impacts of climate variabilities can have negative effects on the development of agro-industries such as the Cotton Development Company (SODECOTON), which has been established in the northern part of Cameroon since 1974 with the mission to manage the cotton sector. According to the France Embassy [22], the company supports more than 160,000 small producers in the northern region.

The cotton sector contributes to Cameroon's development with a representation rate of 1.5% of the gross domestic product (GDP) and 5% of the agricultural GDP. In addition, the country's cotton production represents 11% of African production and 1.2% of world production. Unfortunately, Cameroon is a victim of several hydro-meteorological hazards and climate change, the consequences of which would have a detrimental influence on the country's development and inhibit the realization of Vision 2035's objectives [23].

In addition to SODECOTON, several other agribusinesses are also present in Cameroon, including: (i) palm oil producers, namely Cameroonian Palm Company (SOCAPALM), African Forestry and Agricultural Company of Cameroon (SAFACAM), Swiss Oil Palm Farm Company (SPFS), and Pamol Plantations Plc.; (ii) Cameroon Sugar Company (SOSUCAM); (iii) Cameroon Banana Association (ASSOBACAM), which regroups Cameroon Development Corporation (CDC), Upper Penja Plantation Company (PHP), and Mbanga Plantation Company (SPM); and (iv) Yagoua Rice Farming Exploitation and Modernization Company (SEMRY), Society for the Development of Rice Cultivation in the Mbo'o Plain (SODERIM), and Upper Nun Valley Development Authority (UNVDA). All of them are dependent on agriculture because their raw materials are of agricultural origin, and therefore, they are subject to climatic conditions.

According to Molua et al. [24], Cameroon's economy is essentially agrarian and its main economic development is still based on agriculture and the exploitation of natural resources. However, climatic hazards continue to be one of the factors that cause fluctuations in national income. Their study showed that net income declines as rainfall decreases or as temperatures rise on all the studied farms. The authors reiterate in this study that agriculture in Cameroon is constrained by seasonality and moisture availability. Physical factors such as soil and terrain also have an important influence on agriculture. As a result, the climate remains the dominant influence on crop variety and net income.

In such a context, it seems necessary to review the research and scientific work carried out on the impacts of climate change on the development of agro-industries, particularly in Cameroon. This requires, first of all, a better understanding of the terms "agro-industry" or "agro-industries". According to the Larousse dictionary, "agro-industries" are all industrial enterprises that supply goods to agriculture (fertilizers, pesticides, machinery) and those that process, elaborate, and package agricultural products (food industry) [25]. Agribusiness is part of a broader concept that includes agricultural, fishery, and forestry input suppliers, as well as food and non-food product distributors. According to Silva et al. [26], agribusiness is understood here as a component of the manufacturing sector where value is added to agricultural raw materials through processing and handling operations. They are known to be effective drivers of growth and development. The agro-industrial sector would be defined as the subset of the manufacturing sector that processes raw materials and intermediate products from agriculture, fishing, and forestry. According to Balineau et al. [4], agro-industry includes not only the processing of agricultural products, their packaging into marketable products, and their distribution, but also the associated service activities (supply of fertilizers, seeds, and equipment) and, by extension, all agricultural production systems. In the strict sense of the term, it would only concern food processing and input supply activities. In light of these different terms and definitions, it was proposed that the broad and narrow definitions of agribusiness be considered separately. The agribusiness sector includes not only agriculture-related industries, but also distribution services and commercial activities. Agricultural products, especially grains and oilseeds, are increasingly used as feedstocks for bioenergy production [27]. Bioenergy is limited to agribusinesses that use part of their waste to produce heat for their production lines [28]. Fuel ethanol, which is linked to the sugarcane industry, and biodiesel, which is derived from oilseed plants like palm oil, are two more sources of biofuel [29].

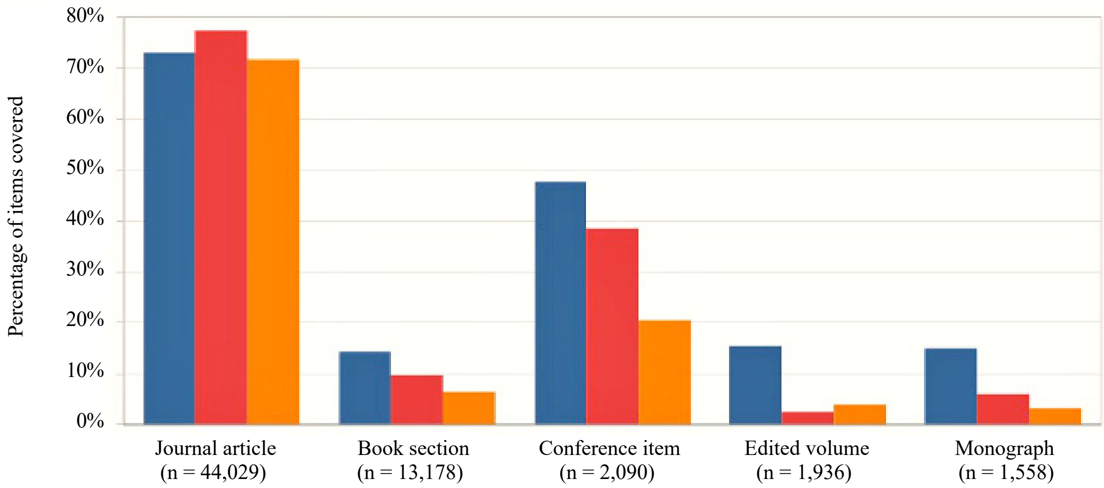
This article first describes the impacts of climate change on agro-industries, particularly those located in Cameroon, and their development in an environmental context deemed uncertain due to climate change, which would have an impact on their productivity. Secondly, it provides a synthesis aimed at highlighting the impacts of climate variabilities on the development of agro-industries in Cameroon based on bibliographic data. Lastly, a point of view is made on climate variabilities as well as on the mitigation measures developed by agribusinesses to reduce their impacts.

2. Bibliometric and bibliographic analyses

A rigorous selection was made of bibliometric and bibliographic data from articles published between 2005 and 2020 on climate change and the development of agro-industries. The quantity of papers would be an indicator of how important the subject is for scientific research.

2.1 *Bibliometric analysis*

Bibliometric analysis was the first methodological approach implemented. It allowed characterizing the evolution of the number of papers published on the issue of climate change's impacts on the development of agro-industries. The analysis was performed using the Microsoft Academic (MA) search engine, which provides comprehensive semantic search functionality. It brought together a wide range of robust citation analysis and worked similarly to Scopus and the Web of Science when focusing on major document types [30-31] (Figure 2).



	Journal article	Book section	Conference item	Edited volume	Monograph
Microsoft Academic	73%	14.3%	47.8%	15.6%	15.1%
Scopus	77.5%	9.7%	38.5%	2.6%	6.2%
Web of Science	71.7%	6.6%	20.6%	3.9%	3.3%

Figure 2. Coverage of the publication output (2008 to 2015) of the University of Zurich according to main document types [31]

The MA is a service offered by Microsoft since 2015 and was introduced to the bibliometric research community by Harzing [32]. According to the author [32], MA presents an excellent alternative for citation analysis. Citation analyses in MA and Scopus yielded consistent results in terms of journal normalized citation score (JNCS), publications of researchers (PR) classes, and evaluation of researchers' publication impact. The MA has the potential to be used for full-fledged bibliometric analyses [33]. Therefore, different searches were conducted by introducing different keywords (Table 1). There were a lot of different articles that had these keywords in the field of "search any topic", "author", "journal", or any combination of these. Searches with different keywords allowed the comparison of the evolution of the number of scientific articles dealing with the impacts of climate change on the development of agro-industries in Africa, in general, and in Cameroon, in particular. The lists of articles were interpreted in terms of the number of papers, years of publication comprised between 2005 and 2020, and the different disciplinary fields of the journals in which they were published.

Table 1. List of keywords used in the bibliometric analysis

Word 1	Word 2	Word 3	Word 4	Word 5
Climate changes	and	agriculture		
Climate changes	and	agribusiness		
Climate changes	and	Agro-industry		
Climate changes	and	energy		
Climate changes	and	livestock		
Climate changes	and	water		
Climate changes	and	soil		
Climate changes	and	Resilience strategies		
Climate changes	and	agriculture	and	Cameroon
Climate changes	and	agribusiness	and	Cameroon
Climate changes	and	Agro-industry	and	Cameroon
Climate changes	and	Agro-industry	and	Development

The bibliometric analysis showed an increment in the number of scientific publications concerning climate change and agro-industries between 2005 and 2020 (Figure 3).

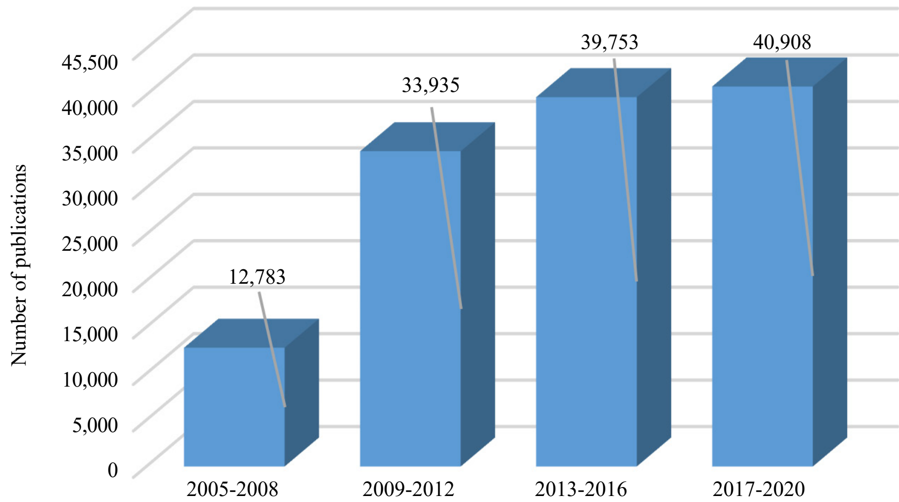
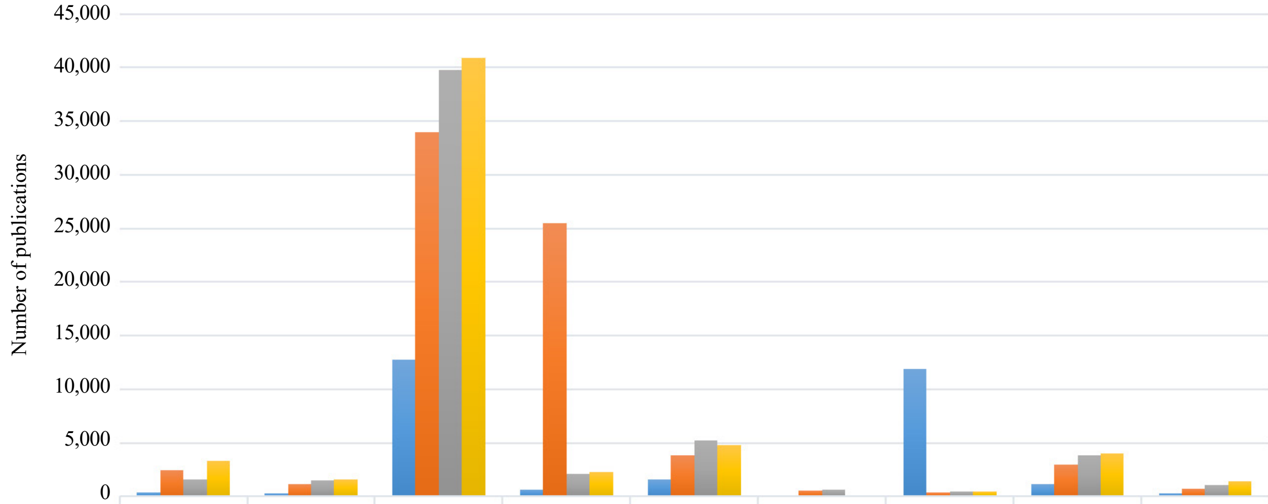


Figure 3. Bibliometric analysis demonstrating a rise in interest in climate change and agribusiness studies from 2005 to 2020

12,783 scientific papers dealing with climate change and agro-industries were found in the MA database from 2005 to 2008, but this number climbed to 33,935, 39,753, and 40,908 for the years 2009 to 2012, 2013 to 2016, and 2017 to 2020, respectively. The number of increments over the years reflected a growing interest in scientific research on this issue.

Based on the MA database results, it can be seen how the issue of climate change, which affects other disciplines (e.g. agriculture, livestock, water, soil, energy science), was thoroughly addressed (Figure 4).



	Climate changes and agriculture	Climate changes and agriculture and Cameroon	Climate changes and agribusiness	Climate changes and energy	Impacts of climate changes	Climate changes and resilience strategies	Climate changes and livestock	Climate changes and water	Climate changes and soil
2005-2008	379	259	12,783	593	1,567	0	11,916	1,135	283
2009-2012	2,492	1,174	33,935	25,522	3,828	517	331	2,979	730
2013-2016	1,626	1,473	39,753	2,135	5,202	607	441	3,875	1,066
2017-2020	3,360	1,544	40,908	2,311	4,784	44	486	4,015	1,417

Figure 4. Number of recorded publications on climate change associated with other disciplines

2.2 *Bibliographic analysis*

The literature was assessed based on the critical reading of more than 200 articles from multiple search engines, including MA, Web of Science, Scopus, Google Scholar, and ResearchGate, which were chosen based on the relevance of their titles and abstracts. All published papers with a title combining "climate changes", "agro-industry", "agriculture", "agribusiness" and "development" keywords were analyzed. Publications with the highest number of citations using other keywords, such as "climate changes", or keywords that were linked together (Table 1), were also used.

2.2.1 *Records of climate change in Cameroon*

Cameroon's economy is diversified and relies mainly on agriculture, livestock, fishing, aquaculture, forestry, and logging sectors. The agricultural sector, which includes agriculture, livestock, fisheries, and forestry, employs about 60% of the population. It also makes up 23% of the country's GDP and has a big impact on other parts of the economy. According to MINEPAT [10-11], the main cash crops include cocoa, coffee, tobacco, cotton, bananas, and pepper, and the country is highly vulnerable to climate change impacts not only because of its exposure, but also because of its low overall adaptive capacity. According to Ngondjeb [34], increased temperatures and decreased rainfall would be detrimental to agricultural productivity, and the economic impact of climate change on agriculture would be very significant. Cameroon has a tropical climate with semi-arid regions in the north and humid and rainy regions in the rest of the country. Due to the African monsoon, which is shorter in the north and longer in the south, almost everywhere has a dry season in winter and a rainy season in summer, while along the coast, even in winter, there can be some showers (Figure 5). The most northern part of the country, along Lake Chad's shores, is the driest area and receives less than 600 mm (23.5 in) of rain per year, while the coast receives more than 3,000 mm (120 in) [35]. To the south, there is a plateau located between 1,600 and 3,900 ft above sea level, where the altitude helps moderate the climate.

Cameroon has equatorial, humid, and dry tropical climates as well as a wide range of soil types that allow it to grow a wide range of agricultural commodities. On average, the annual rainfall is about 1,600 mm. Five agro-ecological zones are identified in the country (Figure 6), including: (i) the monomodal forest zone; (ii) the bimodal forest zone; (iii) the highlands; (iv) the high savannah zone; and (v) the Sudano-Sahelian zone.

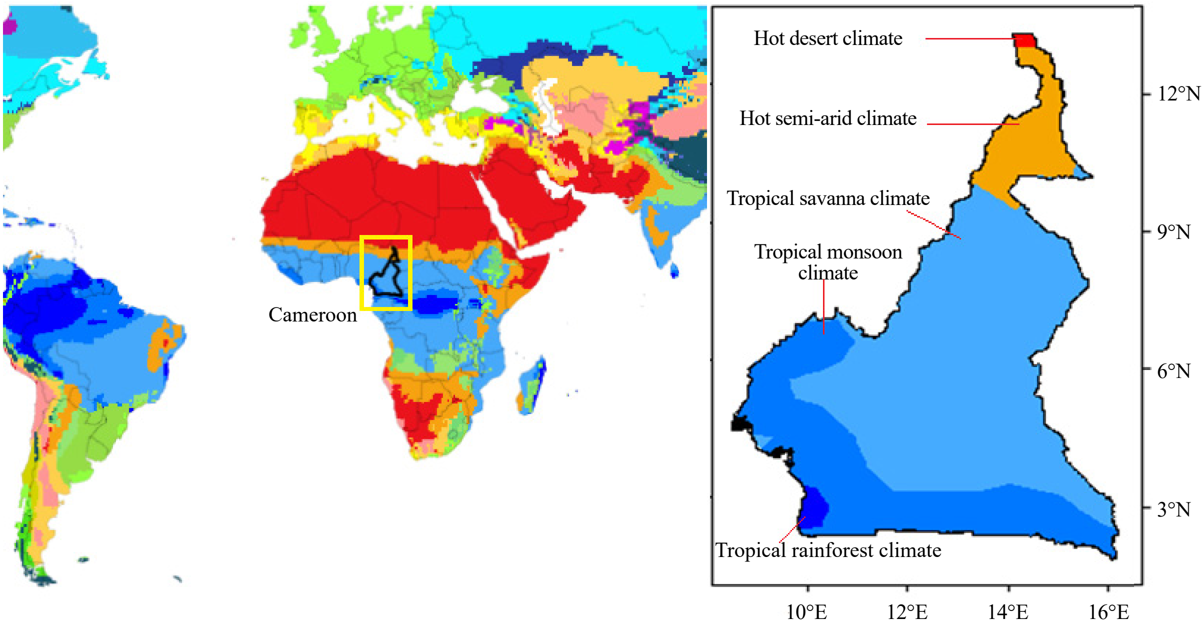


Figure 5. Map of climatic zones in Cameroon

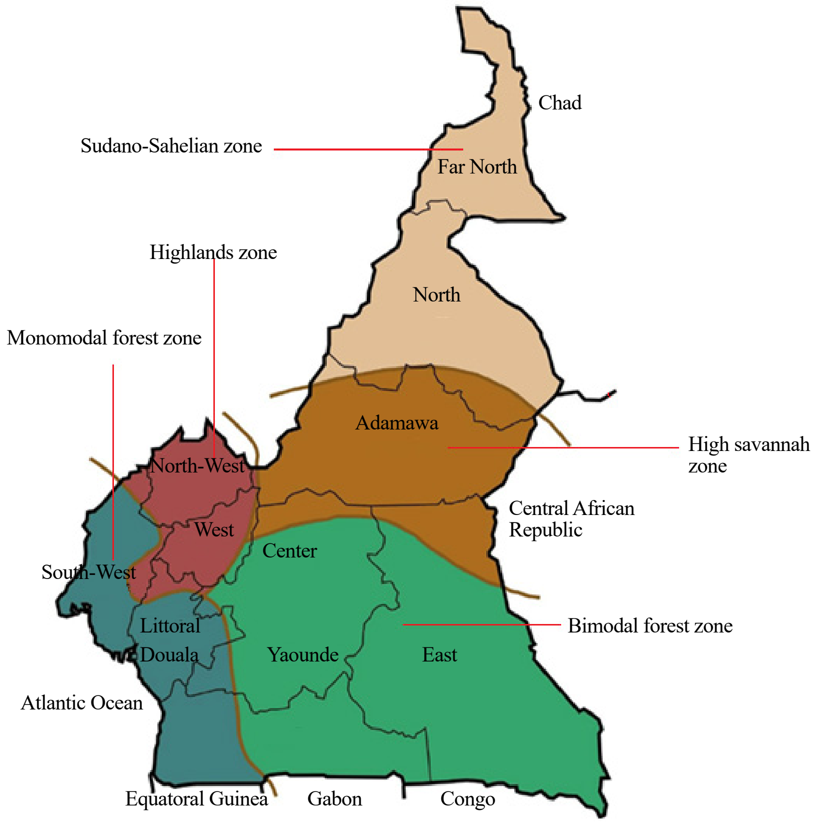


Figure 6. Agro-ecological zones of Cameroon [20]

The monomodal forest zone (central, eastern, southern, and southeastern regions) is located in the equatorial zone. It is characterized by dense vegetation, a vast hydrographic network (1,500 to 2,000 mm/year), and a hot and humid climate with abundant rainfall. This zone is suitable for the cultivation of cocoa, coffee, oil palm, cassava, corn and bananas. In the bimodal forest zone (littoral, southwest and coastal parts of the south), the rainfall is 2,500 to 4,000 mm/year. A large part of the cultivated land is devoted to the industrial production of palm oil, bananas, rubber, cocoa and coffee. However, there is also small-scale subsistence agriculture, including cassava, yams, macabo, and corn. The highlands (west and north-west regions) have a rainfall of 1,500 to 2,000 mm/year. They are considered the country's breadbasket and are densely populated. The average altitude is over 1,100 m. The high plateaus form a zone rich in volcanic soils, favorable for the cultivation of coffee, cocoa, corn, beans, potatoes, and market gardening. The high savannah zone (Adamaoua central and eastern zones) produces maize, millet-sorghum, yams, potatoes, and cotton. The rainy season extends from April to October. The rainfall is 1,500 mm, including 285 mm in August, and the average temperature is estimated at 21.8 °C [35]. The Sudano-Sahelian zone (north and far north) is characterized by a hot, dry tropical climate with little rainfall (an average temperature of 28 to 35 °C and 400 to 1,200 mm/year of rainfall). The dry season lasts from seven to nine months. The vegetation is composed of thorny steppes and grasslands. The region is conducive to cattle breeding and the cultivation of cotton, onions, millet-sorghum, corn, groundnuts, cowpeas, sesame, market garden crops and rice. The Sudano-Sahelian zone experiences more food crises than the rest of the country because of the high level of climatic risks.

Cameroon's climate varies from one region to another (Figure 7). In fact, rainfall decreases from south to north while temperatures increase from south to north. In the central plateau region, rainfall decreases to 1,500 mm; in the north, average annual rainfall is about 750 mm; the wettest part of the country is in the western highlands [36]. According to Sighomnou [37], climate change is a situation where hydrological operating conditions are altered, while Dapi et al. [38] mentioned that the climate of the regions of Cameroon is undergoing climatic change characterized by an increase in temperatures during the dry seasons and early rains (with droughts and floods). This situation is exacerbated in the north and southwest provinces, as well as in the cities of Yaoundé and Douala, compared to other provinces and cities.

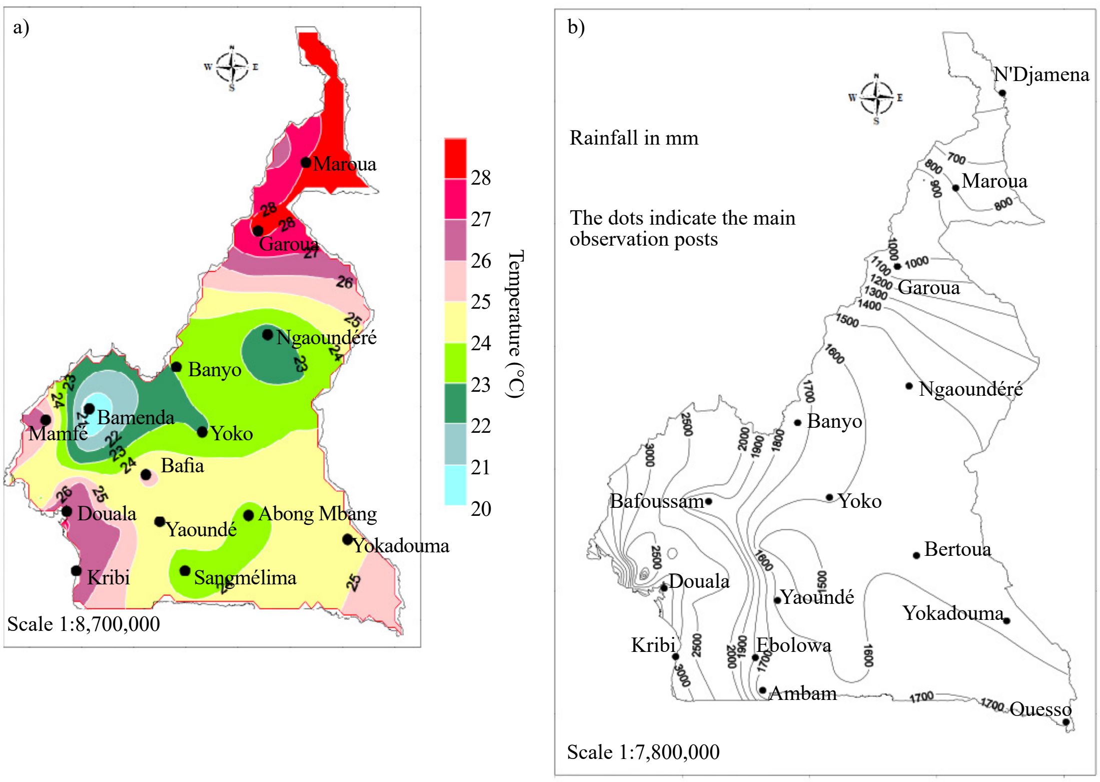


Figure 7. (a) Mean annual temperatures in Cameroon from non-homogenized data between 1955 and 2002, and (b) sketch of interannual isohyets in Cameroon from non-homogenized data between 1940 and 2001 [37]

Cameroon is affected by climate change, which translates into floods, increasing recurrent and catastrophic droughts, violent winds, sandstorms, and haze, to name but a few. According to MINEPDED [39], the above-mentioned hazards affect all sectors of the country. Their increasing brutal nature is surprising to communities and decision-makers, who often find themselves unable to cope with them [40]. Therefore, it would be essential to work on improving the resilience of populations and entrepreneurs in the various industrial and agro-industrial sectors to integrate climate change issues into planning. However, the nature and intensity of the consequences of climate change vary greatly depending on the climate zone concerned. In fact, changes in rainfall patterns have been reported in almost all Sub-Saharan African countries [40]. Table 2 shows the trends in temperature, precipitation and sea level rise in the coming years in Cameroon.

Table 2. Climate trends in Cameroon

Parameter	Climate trends in Cameroon
Temperature	Since 1960, the average temperature has increased by 0.7 °C.
	The number of "hot days" increased by 21.7% between 1960 and 2003.
	By 2090, it is estimated that the temperature increase will be up to 4.7 °C.
	Temperatures are increasing faster and more strongly in the interior, as well as in the north and east of the country, than in the western coastal areas.
Rainfall	Increased extreme precipitation and drought periods.
	Change of the rainy season.
	By 2090, the amount of annual precipitation will decrease or increase by 8 to 17%.
	North: Decrease in annual rainfall amount.
	South: Increase in annual rainfall.
	For example, in 1997 and 2005, the lack of water led to crop losses and famine in the north.
	Since 1960, average rainfall has decreased by 2.9 mm per month and per decade.
Sea level rise	By 2090, depending on the scenario, a sea level rise of between 0.13 and 0.56 m is expected (compared to the sea level between 1980 and 1999).
	According to the national report of the Climate Convention of Cameroon, a rise of between 50 and 90 cm is expected by 2100.

3. Cameroon's temperature and precipitation evolution from 1991 to 2020

According to the World Bank [41], the observed data for average temperature and rainfall from 1991 to 2020 in Cameroon are classified according to climate zones derived from the Köppen-Geiger climate classification system, which divides climates into five main climate groups based on seasonal rainfall and temperature. The five main groups are A (tropical), B (dry), C (temperate), D (continental) and E (polar). All climates, except those in group E, are assigned a seasonal precipitation subgroup. Figures 8 and 9 show the evolution of temperature and rainfall in Cameroon between 1991 and 2020. The default presentation of the data is on a national scale. The observed historical data is produced by the Climatic Research Unit (CRU) of the University of East Anglia.

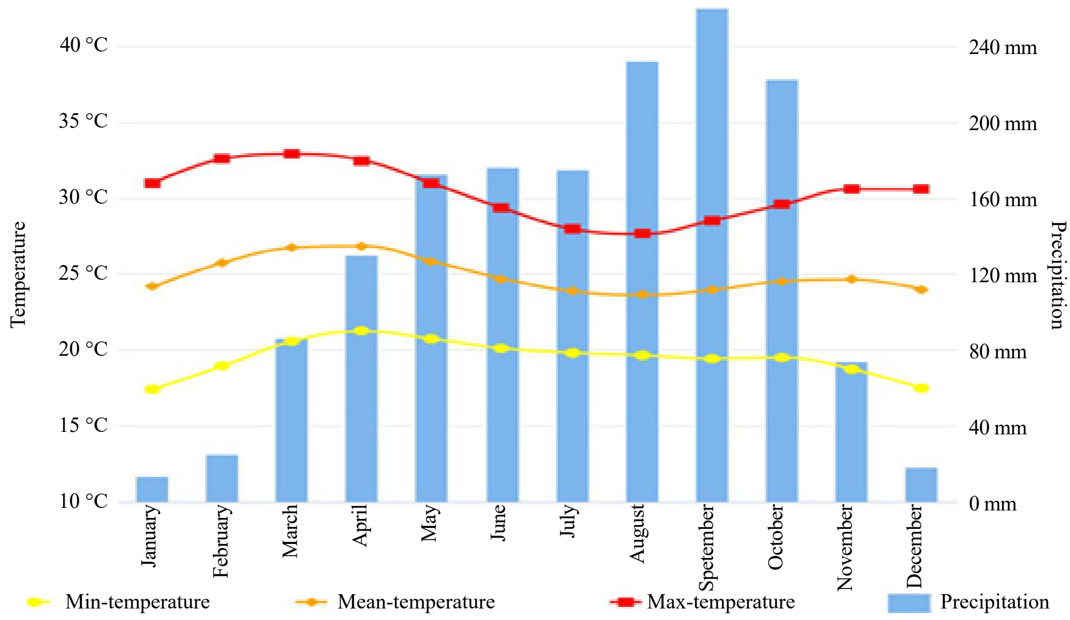


Figure 8. Monthly climatology of precipitation and minimum, mean, and maximum temperatures in Cameroon from 1991 to 2020 [41]

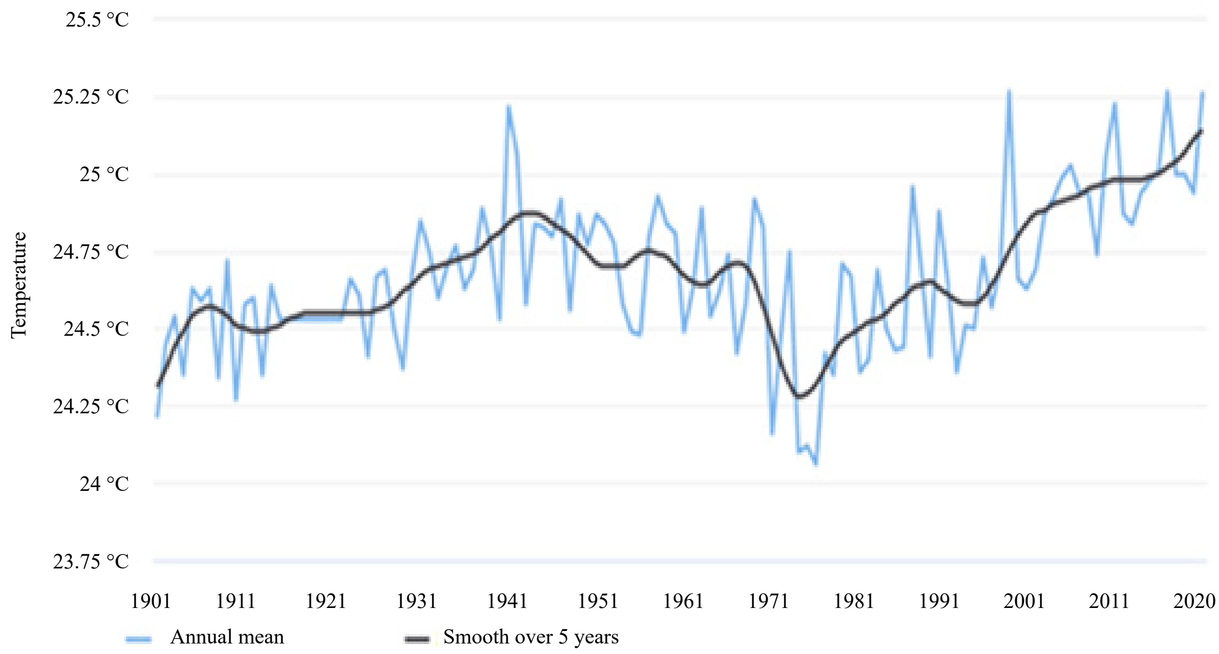


Figure 9. Average annual mean temperature of Cameroon observed from 1901 to 2020 [41]

4. Climate variations and agro-industries production

According to Nguiffo et al. [42], the diversity of agricultural production in Cameroon concerns food and cash crops, such as bananas, cotton, cocoa, coffee, tea, sugar cane, natural rubber, cereals, fruits, vegetables, and tubers. They are all dependent on climatic conditions. Hereafter are the impacts of climate variability on the productivity of some of the agro-industries established in Cameroon.

4.1 *The case of SODECOTON*

SODECOTON was created in 1974. It is located mainly in the far north and north regions of Cameroon (Figure 10), in an area known as the cotton plains. The cotton plains belong to the Sudanian climate zone. Cotton grows and produces better in cotton plains, which are generally characterized by high temperatures (around 30 °C) without frost and a minimum rainfall of 600 mm well distributed over the entire crop growing cycle, as opposed to nearly 700 mm required in strict rainfed cotton cultivation [43].

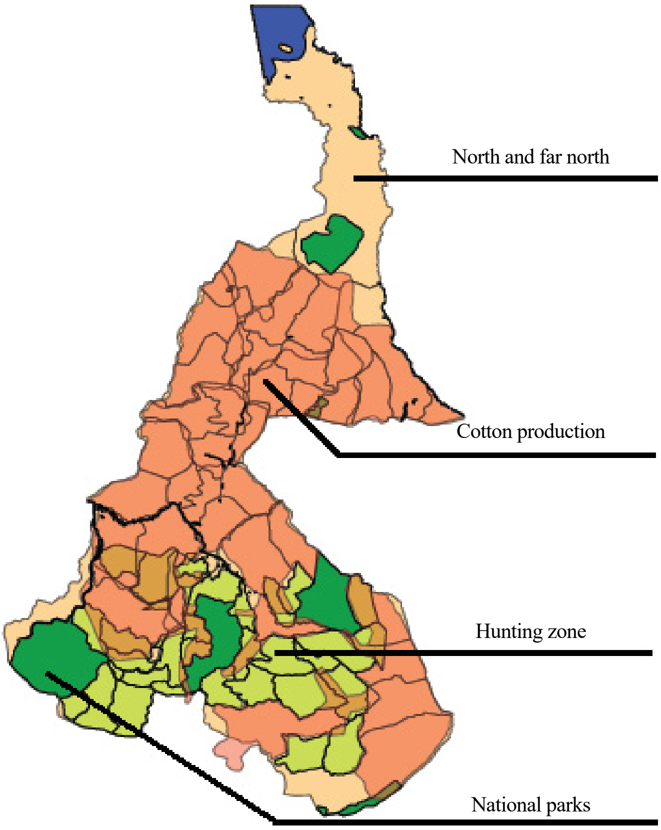


Figure 10. Cotton production area and overlap with protected areas in the Far North and North regions [44]

SODECOTON is involved in an integration of activities by taking care of the supply of production factors upstream and purchasing cotton seeds from farmers. This company processes cotton, which involves separating the fiber from the plant's seeds [44]. The agro-industry processes cotton and soybean seeds to produce table oils (namely Diamaor and Soyor, respectively) and to manufacture animal feed. After three years of losses totaling USD 59,616, SODECOTON achieved a profit of 4.3 billion XAF between 2016 and 2017. It aimed to increase its production from 400,000 tonnes in 2021 to 600,000 tonnes by 2025 [44]. The company would not rule out the possibility of introducing transgenic cotton in Cameroon, where studies began in 2012 and results were expected in 2018 [44]. Mbodiam [45-47] claims that the introduction of genetically modified organisms (GMOs) in cotton has made it possible to plant genetically modified cotton that provides very good yields. The author also indicates that the development of a reasonable agronomic program with insecticide treatment will make it possible to manage pest populations in the cotton zone while still obtaining good production. According to EcoMatin [48], SODECOTON denies any use of GMOs to increase its production. This false information would have been published in EcoMatin's N˚205 edition on December 10, 2018 in an article entitled "Cotton: Despite the controversy, SODECOTON opts for the use of GMOs" from which SODECOTON would have provided an update to the newspaper's editors to clarify the situation. However, the author mentions that experiments on GMO cotton and other research projects are part of the SODECOTON/IRAD/CIRAD five-year tripartite agreements. As the subject of genetically modified cotton has not been retained for the period of 2017 to 2022 by the Ministry of Scientific Research and Innovation of Cameroon, SODECOTON would have suspended this research activity, which is still in the experimental stage.

Based on a study conducted by Gérardeaux et al. [49], the effects of climate change on cotton yields were investigated using the "CROPGRO" cotton cropping system model. It appears that despite the threat of climate change on most crops, its impact on cotton fields would be less until 2050, probably due to CO_2 enrichment and other conservation farming practices adopted by Cameroon. The work would have unexpectedly demonstrated that climate change in Northern Cameroon from 2005 to 2050 will have a positive effect on cotton yields with an increase of 1.3 kilograms per hectare per year (kg/ha/yr) in yield, especially if conservation farming systems are adopted. Based on observations made in stations and field plots in Northern Cameroon between 2001 and 2005 and in 2010, it was estimated that a 0.05 °C increase in temperature would raise the annual yield of fields by 1.3 kg/ha/yr, resulting in a rise of more than 2.5 kg per hectare by 2050. Over the last five years, the number of producers has decreased dramatically, but yields have significantly improved (Figure 11) [44].

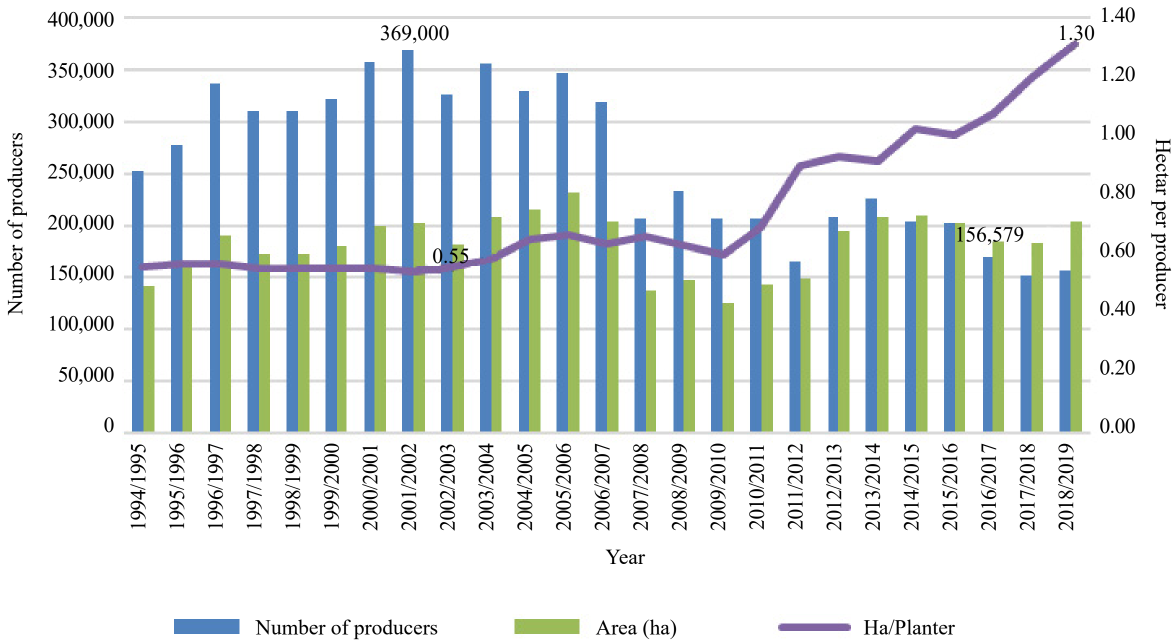


Figure 11. Evolution of the average cotton area per producer (1994-2019) [44]

Cotton plants require a long frost-free period, plenty of heat, and lots of sun. This plant prefers humid and warm climates. Cotton seeds will have a low germination rate if the soil temperature is below 15 °C. During the active growth phase, the ideal air temperature is between 21 and 37 °C. Temperatures above 37 °C are undesirable. The average cotton plant can survive temperatures of up to 43 °C for brief periods of time without much damage, but this also depends on the humidity level [50]. Cotton is particularly sensitive to boron deficiency, which causes dark rings on the petiole, necrosis at the petiole's pith, malformed flowers, and dwarf plants with abnormal or "crumpled tops". Cotton is also very sensitive to aluminum and manganese toxicity. The optimum pH is between 6.0 and 7.0 [51]. It is important to grow cotton in rotation with other crops, because repeated cultivation of cotton in the same field leads to lower yields. Crop rotation and cropping patterns not only help to improve and/or maintain soil fertility, but also prevent the emergence of pest, disease and weed populations. Crop diversity also reduces producers' economic risks, making them less vulnerable to crop failure and price fluctuations [51].

Soybeans are best grown on productive soils at an elevation of about 2,000 m above sea level with a pH range of 4.5 to 8.5, which differs slightly from cotton production conditions. Soybeans thrive at temperatures between 21 and 30 °C

[52].

4.2 *The case of SOCAPALM, SAFACAM, SPFS, CDC, and PAMOL*

The monomodal agro-ecological zone and the bimodal forest agro-ecological zone are the most suitable for oil palm cultivation (Figure 12). There are, however, a few pockets in the northwest, west, and Adamaoua regions [53]. The palm tree grows primarily in the forest area of southern Cameroon and in the littoral region. Oil palm grows best in Cameroon's coastal zone (southern, coastal, and southwestern regions) (Figure 12) [54]. Oil palm cultivation requires: (i) high daily temperatures throughout the year, ranging from 25 to 28 °C, with minimums of 18 °C in the coldest months; (ii) at least 5 hours of sunlight per day; and (iii) rainfall ranging from 1,800 to 2,400 mm/yr [53]. A long drought that lasts more than 90 days is a big problem for the growth of oil palms.

Oil palm plantations cover 375,000 hectares of land shared between industrial plantations, entrepreneurs, and small farmers. The annual production of palm oil has increased from 270,000 tonnes in 2013 to 413,000 tonnes in 2018, while the demand peaked at 1,179 million tonnes in 2018 [53]. According to Hensel et al. [55], palm oil is the most efficient energy source for non-electrified palm oil production, followed by diesel, gasoline, and human energy. The authors also point out the risk of competition between food use and energy conservation of certain agricultural products, which could jeopardize food security in many contexts. Meanwhile, national palm oil production remains in deficit, and experts estimate that Cameroon will need to import approximately 100,000 tonnes of palm oil per year to meet its population's needs, given that demand is increasing by about 3% each year. Unfortunately, a decrease in rainfall leads to an increased soil water deficit [56]. Corley et al. [57] have predicted a yield decline of 2.88 t/ha of fresh fruit bunches per 100 mm of water deficit. The above-mentioned decrease in rainfall from the south to the north of the country, as well as its uneven distribution, could increase and potentially cause water shortages in fields that have been planted, thereby causing crop depletion.

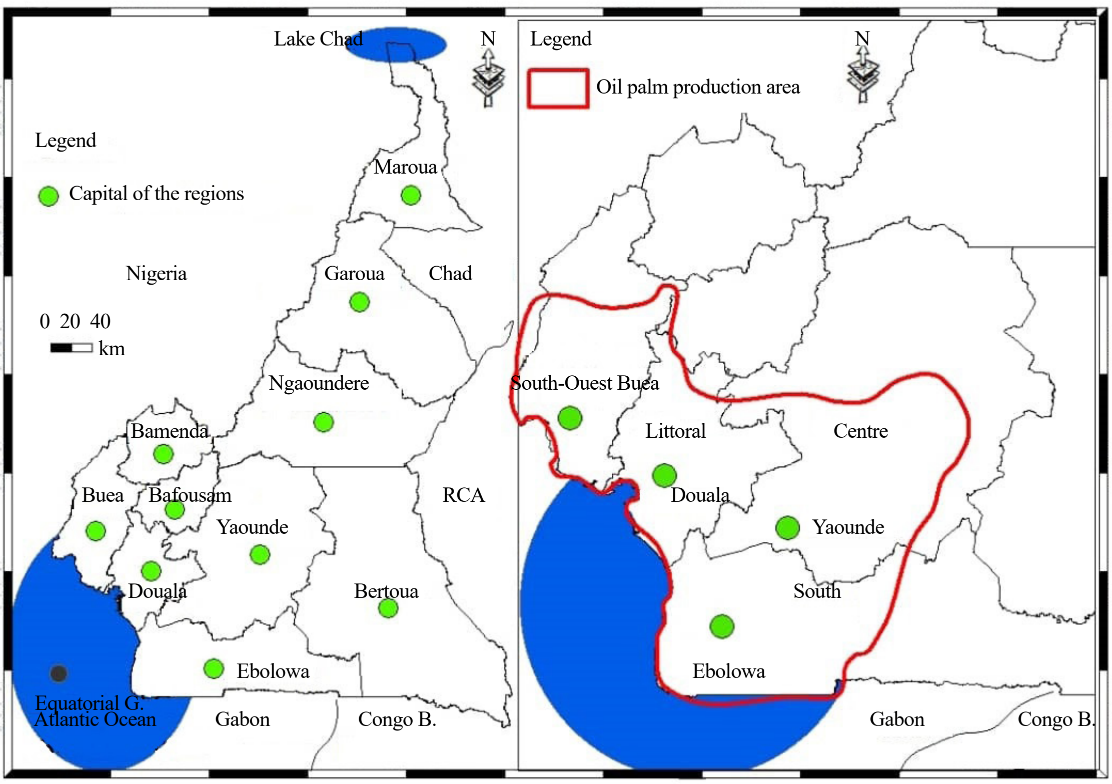


Figure 12. Location of the major oil palm production basins in Cameroon (agro-industrial plantations) [54]

4.3 *The case of SOSUCAM*

SOSUCAM is one of the largest sugar cane plantations in Cameroon, with 46,207 hectares of plantations located on two sugar manufacturing sites, M'Bandjock and N'Koteng. This company was founded in 1965 and is located approximately 100 km north of Yaoundé, along National Road No. 1, in the Central Region's Mbandjock and Nkoteng, between 11° 51' and 12° 10' east longitude and 4° 20' to 4° 35' north latitude (Figure 13).

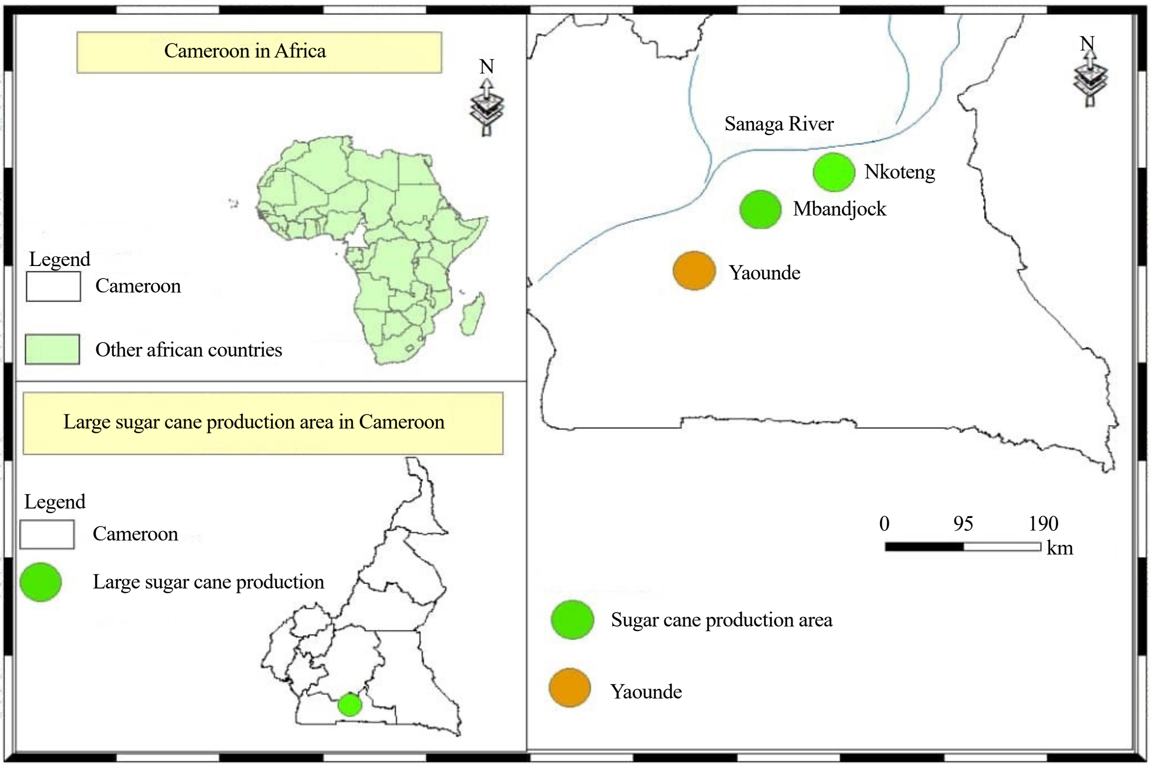


Figure 13. Location of the SOSUCAM sugar complex [58]

According to Société d'Organisation de Management et de Développement des Industries Alimentaires et Agricoles (SOMDIAA) [59], SOSUCAM produces 130,000 tonnes of sugar cane each year. This company belongs to the SOMDIAA group, a French company, which holds 72.72% of its capital. Its remaining capital is divided between the Cameroonian State and private Cameroonian shareholders, including SOSUCAM employees. With 1.08 million tonnes of sugar cane crushed in the two factories, SOSUCAM produces approximately 105,000 tonnes of sugar each year, including 17,000 tonnes of sugar cubes. It sells for approximately 100,000 tonnes on the Cameroonian market and supplies Chad with extra-refined sugar, which is used in breweries. In order to meet the growing needs of the Cameroonian market, SOSUCAM has expanded the area of sugar cane fields to strengthen its production capacity. In addition to the exploitation of land for the cultivation of sugar cane, SOSUCAM offers several other services, such as the production and distribution of refined sugar, the production and distribution of blond sugar, and the production of electrical energy [60]. During the Reunionese Association for the Agricultural and Sugar Development (ARTAS)/French Sugar Cane Association (AFCAS) 2012 Sugar Congress, the development plans of SOSUCAM Nkoteng for 2017 were presented, as well as its production and energy delivery capacities in relation to its geographical location. Table 3 shows a crushing forecast of 1,044,154 tonnes of crushed sugarcane in 2017 over a period of 210 days. This is based on an average hourly rate of 225 tonnes/hectare [60].

Table 3. SOSUCAM's development plan in 2017 [60]

SSC2 NKOTENG (Year)	2013	2014	2015	2016	2017
Campaign days	200	205	212	220	210
Crushed sugar cane	798,440	852,765	926,772	983,077	1,044,154
Sugar product	82,327	88,134	97,618	105,650	112,382

As a result, starting in 2017, the N'Koteng factory will be able to grind 225 tonnes of sugar cane each hour, while the M'Bandjock factory will be able to produce 165,000 tonnes of sugar cane per harvest across the SOSUCAM plantation (61,774 hectares) [61]. SOSUCAM is dealing with soil degradation problems due to unexpected heavy rains related to changes in rainfall patterns. Sugarcane, like most food and industrial crops, fails to adequately cover the soil before the critical period of heavy rainfall due to natural factors, particularly the aggressiveness of rain [61]. In fact, the production areas, which include cultivated fields and exploitation tracks, cover nearly 20,000 hectares (varying in width from 3 to 12 m). The cultivated areas are divided into plots grouped into blocks, forming estates [58].

According to L'Economie [62], SOSUCAM loses about 30,000 tonnes of sugar per year due to climate change, which has the effect of limiting yields to between 5.5 and 6 tonnes/hectare, instead of the target it had set for itself of 7 tonnes. Yield losses due to climatic hazards oscillate between 1 and 1.5 tonnes. This agro-industry would lose up to 30,000 tonnes of sugar each year due to the severity of the dry seasons, which is a huge volume for an agro-industry that is projected to reach 160,000 tonnes in 2020. Climate change is causing SOSUCAM to lose about 23% of its production (130,000 tonnes), a situation that is very detrimental to the company. To address this situation, SOSUCAM decided to proceed with the irrigation of plantations, with the objective of acquiring 5000 hectares in ten years. The project was launched in 2015. Plantations will be irrigated on 4000 hectares on the Nkoteng site and 1000 hectares on the Mbanjock site, with a budget of USD 75.2 million to be invested by 2023. SOSUCAM has achieved a 60% gain in sugarcane yield (10 tonnes/hectare) on the irrigated plots. This trial has proven that during a period of drought, sugar synthesis and accumulation are favored.

4.4 *The case of ASSOBACAM*

ASSOBACAM was established in 1988 after the dissolution of the former Office Camerounais de la Banane (OCB) and grouped together the industrial banana producers of Cameroon, including CDC, PHP, and SPM. The missions of ASSOBACAM are: (i) to study, implement, and monitor all operations to promote the export and competitiveness of bananas from Cameroon; and (ii) to represent and defend the interests of the entire banana sector in Cameroon, particularly with respect to third parties and national or foreign public authorities [63]. According to ASSOBACAM, in the first quarter of 2021, Cameroon exported 54,900 tonnes of bananas, an increase of 5,082 tonnes compared to the year 2020, when exports were only 49,818 tonnes. This performance was mainly due to exports by the state-owned agro-industrial company CDC. According to Mbodiam [64], PHP exported only 45,522 tonnes of bananas between January and March 2021, compared to 45,893 tonnes during the same period in 2020. According to Sotamenou et al. [65], banana and plantain production is negatively affected by high temperatures (above 24 °C) and low rainfall levels (between 1,500 and 2,000 mm). However, banana and plantain agriculture are still dependent on climatic hazards such as rainfall and temperature.

4.5 *The case of SEMRY and UNVDA*

According to CamAgro [66], SEMRY is a state-owned company, created in 1971 in the Far North region. SEMRY is placed under the technical supervision of the Ministry of Agriculture and Rural Development and under the financial supervision of the Ministry of Finance. It was mandated to undertake (i) the creation, acquisition, operation, and development of all agricultural activities, particularly rice cultivation, in the Logone Valley, as well as (ii) the creation and management of all hydro-agricultural and road development works, particularly in the public domain, necessary for the exploitation of agriculture in the floodable zones of the Logone Valley, in accordance with the clauses of the specifications and the concession decree.

After SEMRY, other support structures were created: SODERIM and UNVDA. They provided technical assistance to private rice farmers for the production and marketing of rice. However, irrigation was affected by the crisis of the late 1970s, which particularly affected the large public enterprises in this sector. Following the state's departure from the productive sector, the state implemented changes that led to the dissolution of certain corporations, including SODERIM, and the restructuring of these agro-industries (SEMRY and UNVDA) [67].

Rice cultivation would be the most vulnerable to global warming, although some studies suggest that rising CO_2 levels may initially boost yields [68]. Unfortunately, this situation will not last long, and Asia and sub-Saharan Africa will be among the region's most severely affected by climate change. Asia produces nearly 90% of the world's rice, while global rice consumption is growing at the fastest rate in sub-Saharan Africa. The most vulnerable cropping systems are those practiced on the hills and rainfed plains, which represent 80% of the rice-growing land in Africa [69]. In terms of imports, the share of imported food in West Africa, Cameroon, and Chad climbed from 7 to 25% between 1961 and 2011 [70]. The high import rate may represent local production's failure to match agribusinesses' and African communities' needs. Experts expect a rise in world prices as a result of global warming; the challenge is therefore very real, especially in the cities of sub-Saharan Africa, where dependence on cereals is high, mostly because wheat and rice account for at least half of the consumption of starch products [71].

5. Viewpoint on climate change and agribusiness development in Cameroon

Most of Cameroon's agribusinesses derive most of their raw materials from agriculture, which is dependent on climatic conditions. In addition, these agribusinesses have a significant impact on the country's economic growth, contributing to 5% of the GDP. Despite the reported positive effects of climate change on certain crops such as cotton, it is noted that climate change could cause more harm than good. According to Gérardeaux et al. [49], the increase of CO_2 in the atmosphere due to the warming of the earth's surface would have positive effects on the production of cotton, which remains one of the main raw materials of SODECOTON's agro-industry. Conversely, the increase in temperature (> 30 °C) and decreasing rainfall would be very unfavorable to the growth and yield of oil palm and banana/plantain crops, which are providers of raw materials for SOCAPALM, CDC, PHP, and SPM agro-industries. According to Amougou [72], climate change is expected to be an obstacle to Cameroon's medium-term national development goals; despite its low greenhouse gas emission rate of 0.03% of global emissions, the country will not be immune to the effects of climate change. Cameroon was a signatory to the United Nations Framework Convention on Climate Change in 1994 (UNFCCC) and the Kyoto Protocol in 2002. Cameroon also ratified the Paris Agreement on Climate Change in 2016 and participated in the Glasgow 2021 Climate Change Conference, which takes place from November 1 to 13, 2021. It shows that climate change occupies a prominent place. Therefore, the development of resilience strategies to cope with the adverse effects of climate change remains a battlefield to be addressed at the forefront. The above-mentioned actions are consistent with the study conducted by Chia et al. [73], which indicates that Cameroon, like other developing countries, has developed approaches to meet national and global commitments to climate change adaptation and mitigation.

6. Conclusion

Climate change has a considerable impact on the vast majority of agro-industrial enterprises established in Cameroon. Nevertheless, a positive improvement in cotton yields with an increase of 1.3 kg/ha/yr in yield has been reported on cotton due to the increase of CO_2 in the atmosphere. Climate change is causing SOSUCAM to lose about 23% of its production due to the observed increase in temperature and decrease in rainfall, which is of concern for agriculture and would result in a drop in yield of 2.88 t/ha of fresh fruit bunches per 100 mm of water deficit. Agro-industrial development in an unpredictable environment, certainly linked to climatic conditions, remains a great concern in Cameroon. Given the country's Vision 2035, by which it is determined to become the new industrialized and emerging country by 2035, Cameroon intends to increase its agro-industrial production capacity to ensure its food self-sufficiency and to be the distributor of products throughout Africa. However, climate change would be a factor in slowing down its development plan if nothing is done. Climate change and agribusiness have been the subjects of much research since

2005, as shown by the quantity of related scientific publications. Given the adverse effects of climate variability, there is an urgent need to define more adaptable and sustainable resilience strategies to cope with the depletion of agricultural production. Hence, the development of some varieties resistant to certain effects of climate change should be carried out by agricultural research centers. Thus, research will have to develop effective tools and define more adaptable and sustainable resilience strategies to cope with climate variability. The tools must be co-constructed by climate change science experts and agribusinesses to foster their application. They should guide agribusinesses' decisions at each stage of the investment project, especially upstream, in order to take into account the climatic parameters necessary for project implementation and development. The phenomenon of climate change is evident in Cameroon and constitutes a real constraint to agro-industrial development.

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Conflict of interest

The authors declare no conflict of interest.

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