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Research article

Perception and adaptation strategies of forest dwellers to climate variability in the tropical rainforest in eastern Cameroon: The case of the inhabitants of the Belabo-Diang Communal Forest

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A R T I C L E I N F O

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A B S T R A C T

The design of appropriate adaptation strategies to the impacts of climate change requires a contextual study of local perceptions due to the non-homogeneity of climate in a given agro-ecological area. The research objective of the current study aims to examine the evolution of climate parameters from 1983 to 2019 linked to the perceptions of local populations and appropriate adaptation measures in the Belabo-Diang Communal Forest of Cameroon. The methodological approach includes collecting and analyze climate data from 1983 to 2019; and surveying existing local perceptions and adaptive strategies among 540 households using semi-structured questionnaires. A significant increase in temperature of about 1 °C over 36 years (1983–2019) and a non-significant decrease in precipitation (95.36 mm) over the same period were observed. Local perceptions related to climate change vary according to the sector of activity and are mainly associated with more heat in the dry season (90%), late onset of rains (84%), drought recurrence (82%), less rainfall during the year (80%), and increase in the duration of drought (80%). For 82–100% of households, according to the activity sector, no appropriate adaptation measures to climate change were applied depending on activities. The adaptation

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measures used by less than 0–20% of respondents, include mainly the abandonment or change of activity, and modification of the agricultural calendar. With the lack of appropriate and adequate adaptation measures by the riparian populations, this study appears necessary to inform policy-makers of the need to develop and implement more appropriate strategies to enable the riparian people living in forest area of Cameroon to better adapt to these effects of climate changes.

1. Introduction

It is now indisputable that human influence has contributed to significant warming of the earth's surface, resulting in rapid and widespread changes in the atmosphere, oceans, cryosphere, and biosphere [1]. Despite international efforts observed until today to limit global warming processes, global temperatures have been warmer over the past four years than any previous year since 1850, with temperatures increasing from 0.8 °C to 1.3 °C [1]. Hence, the rise in climate has led to a change in the frequency of meteorological events with strong variations depending on the ecological or phytogeographical area. For instance, extreme heat and heavy precipitation events are becoming more persistent in northern Europe in particular; soil droughts in regions such as the Mediterranean basin, southern and western Africa, and western North America [2].

The impact of climate change are becoming evident in all ecosystems around the globe [3–5], with visible effects on physical and biological systems [6–11]. Species survival and ecosystem integrity are recognized as the resulting threats of these changes [12–14]. Recent studies point to intensifying droughts in some areas [15,16], with more profound effects on soil water availability and agricultural yields [17]. These impacts also affect local communities' socio-economic and cultural systems that depend directly on their environment [18,19]. For Coles and Scott [20], due to economic constraints (e.g., cost of adaptation), traditional knowledge (e.g., their in-depth understanding of the forest and its resources; availability of resources) is privileged over seasonal climate forecasts in defining agricultural and livestock practices.

The effects of climate change are now easily perceptible especially in Africa, where it is increasingly accentuated by deforestation and forest degradation. Thus, it is becoming urgent to take an interest in temporal variability, which is due to the fact that the climatic

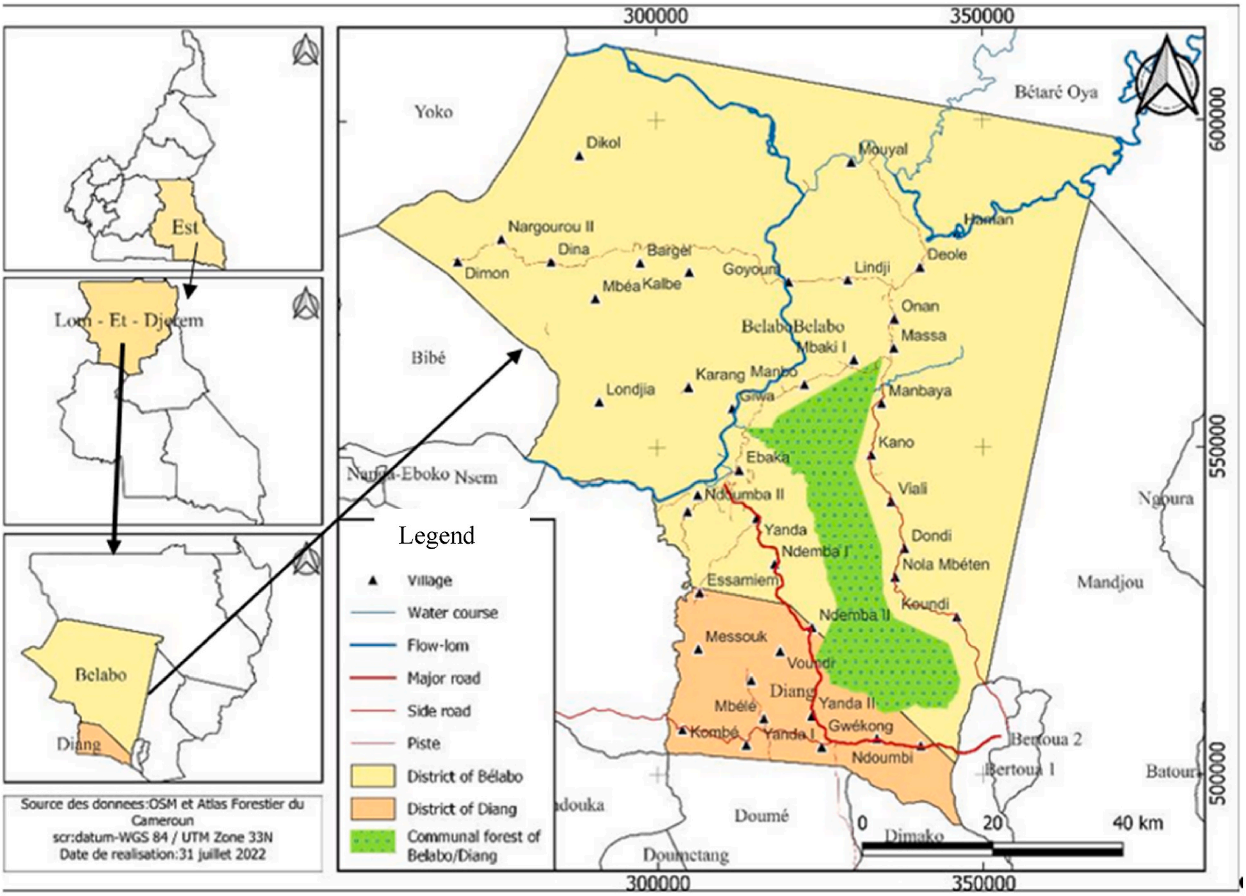

Fig. 1. Location of the study area.

parameters, which varied over time as a result of the planet's global seasonal cycle, also show different evolutions depending on the region. However, those exposed to long periods and experiences (droughts, floods, heat waves, cold snaps, etc.) are the most knowledgeable and adopt sustainable behaviours and/or appropriate adaptation practices [21]. Indeed, this information helps to communicate risk trends to the population and policy-makers [22–24]; this aims better to structure adaptation strategies in response to climate change-induced threats. The consequences of climate change could undermine affected countries' efforts. Taking the case of Cameroon where a recurrence of unusual extreme weather events, such as high winds, high temperatures or heavy rains that endanger the communities, ecosystems and the services they provide, several incentives measures like National Climate Change Adaptation Plan [25] have been developed to enable the population to adapt to climate changes. For example, the valorization of local traditional and scientific knowledge related to environmental constraints [26] and the strategies for assessing sensitive sectors in the agro-ecological zones of Cameroon's bimodal forests indicate the vulnerability of the agriculture, livestock, fisheries and aquaculture sectors, biodiversity, the harvesting of Non-Timber Forest Products (NTFPs), sanitation and health [27].

In fact, local's perception of climate change appears to be the first step towards decision-making and the development of climate change adaptation/mitigation strategies [28–30]. Although literature on local communities' perception of climate change and the adaptation strategies used has been published in the last decade [31–33], most of the work has been limited to predominantly agricultural areas [34–36] without any insight into forest areas. Understanding and predicting annual, decadal, or multi-decadal variations in the recent past has become a challenge for climate scientists [37,38]. Indeed, Ngute al [33]. concluded that temperature varies from one area to another depending on the activities carried out in these area. Moreover, the link between the perception of local populations of Cameroon and meteorological data to assess climate change is not available in the literature. It is therefore becoming urgent, in a context where all the debates are focused on biomass technologies (Carbon Capture and Storage) to mitigate climate change, to first understand how these phenomena are perceived by riparian people of the forest areas linked to adaptive strategy put in place by them to face climate change. The local people of Belabo-Diang Communal Forest (BDCF) perceived the effects of climate change variability in their daily lives and have developed adaptive strategies to face them, which is the hypothesis of this study. So this study seeks to evaluate the climate change and adaptability perceptions by local populations in the Belabo tropical forest zone. This is done through the analysis of the evolutionary trends of the climate, the analysis of local perceptions and adaptation measures.

2. Material and methods

2.1. Study area

This study was conducted in the villages bordering the BDCF, located in the municipality of Belabo, Lom & Djerem Division in East Region of Cameroon (Fig. 1). The municipality of Belabo is geographically located at latitude 4°36 - 5°06 North, and longitude 13°17-13°38 East and comprises 53 villages with an estimated population of 45,559 inhabitants. The soils are essentially ferralitic and suitable for agricultural activities. The hydrographic network of the area is very dense and favorable for fishing activities. The climate prevailing in the locality is the equatorial type characterized by alternating four seasons: two dry and two rainy seasons. The average temperature of this study area vary between 23 °C and 25 °C and average cumulative rainfall is 1800 mm/year [39]. The forests are dense humid forests of the Guinean-Congolese domain [38]. From a phytogeographic point of view, this zone is characterized by semi-deciduous forests with a rich diversity of flora and fauna [40]. Agriculture, NTFP collection, logging, and fishing are the main economic activities on which the riparian populations depend for their livelihood [40].

2.2. Data collection

2.2.1. Collection of climate data

Given the absence of weather stations in the Belabo area, climate data were obtained from the Cameroon Ministry of Transport, the Cameroonian institution managing meteorological data, especially from the "noaa ncep cpc fews Africa" for temperature and "noaa ncep cpc fews africa. data arc2" for rainfall. Since only meteorological data (daily temperature and monthly rainfall) from 1983 to 2019 (corresponding to a 36-year interval) were available, our study was limited to assessing climate change based on this time interval.

2.2.2. Surveys on residents' perceptions of climate and adaptability measures

The survey was conducted in 20 of the 53 villages in the municipality of Belabo. The choice of villages surveyed was based on the size of the population and its proximity to the BDCF after an analysis of the 2010 Cameroon population census data from the "Bureau Central des Recensements et des Études de Population" [41].

Households were selected for the survey based on their availability, hospitality and willingness to contribute to the study's objectives. In addition, their length of time in the village was a key factor, based on the assumption that people who had lived in the area for at least 15 years could identify significant changes in climate and environment and strategies that they have developed to face them.

The targets in the households were essentially the heads of households, and when possible, they were assisted by family members who could provide confident answers concerning our questionnaire. The questionnaire was designed according to literature review and local realities. It is important to note that the questionnaire was pre-tested in some nearby households and amendments were made to improve and provide a definitive questionnaire that was used for household's data collection.

The methodology used is aimed at an optimal socio-demographic sampling of the population [42,43].

The sampling methodology adopted for determining the sample size for this study was based on the Yamane [44] formula presented as follows:

$$n = N / \left(1 + N\,(e)^2\right)$$

where: n = sample size N = population size e = the acceptable sampling error (95% CI). Considering that the total number of peasant households in the study area was roughly 1348, the sample size of 540 peasant households was just sufficient for the study, working with an error margin of 5%.

Household surveys were conducted using semi-structured questionnaires that were administered to the head of households. The questionnaire in this study was designed to identify the local people's perceptions of climate variability and change and the coping strategies they have developed over time. Questions such as have you ever heard of climate change? Do you think that climate variability and climate change are a reality? Have you developed any adaptation strategies? Were some keys part of this questionnaire.

2.3. Data analysis

Climate variation data of 1983–2019 for temperature and precipitation of Belabo were analyzed using R software. An annual average and anomaly of temperature and precipitation are used to estimate the linear regression of the climate trend from 1983 to 2019. The temperature/precipitation anomaly was calculated using the following formula [45]:

$$\grave{A}i = Ai - \bar{A}/\sigma(A)$$

where Ài is equal to the Reduced Center Anomaly for year i, Ai is the value of the variable, Ā is the series mean, and (A) is the series standard deviation. A positive anomaly of precipitation means that the temperature was warmer than normal; a negative anomaly indicates that the temperature was cooler than normal.

The anomaly evolution diagram was used to define the series (sub-periods) under which the student t-test with a 5% confidence level was used to test the significance between the identified sub-periods. Linear regression analyses of climate trends were performed for each of the sub-periods. Because of the fluctuation in precipitation, it was essential to identify sub-periods. Therefore, the series used for temperature, namely 1983–2000 and 2001–2019, was used for the significance test of precipitation data. On an annual scale, the difference between the sub-periods shown by the precipitation anomaly curve can be considerable, but this analysis is of no real climatological interest because it applies to a much too small-time span. For the sake of homogeneity, the previous sub-periods have been maintained.

The perception data and the main coping strategies identified were analyzed using descriptive statistics. The multivariate logistic regression model was used to estimate the observed and unobserved influence of the explanatory variables (age, gender, education, occupation, and settlement time) on the main perceptions.

3. Results

3.1. Evolutionary trend of climate parameters

3.1.1. Temperature variations from 1983 to 2019

The actual evolutionary situations of annual mean temperatures for the period 1983–2019 are shown in Fig. 2. The mean

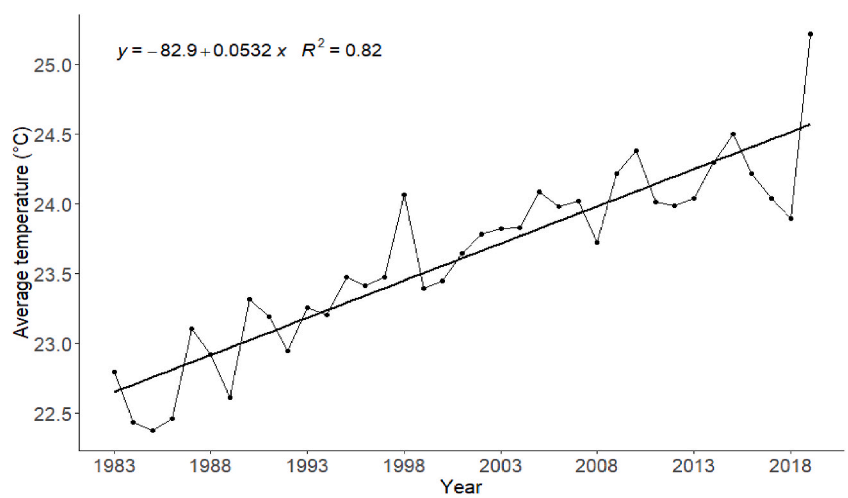

Fig. 2. Trend line of annual mean temperature change from 1983 to 2019.

temperature was 23.6 ± 0.6 °C, which served as a reference for the study period. Furthermore, the average minimum temperature was 22.4 °C in 1984 and 1985, while the average maximum temperature was 25.2 °C in 2019, indicating a difference of 2.8 °C over 37 years. The evolution curve does show a significant peak in 2019 (Fig. 2), representing the warmest year. The temperature increases of 0.8 °C per decade leads to a temperature increase of 3.39% per decade.

The diagram of the evolution of anomalies during these years shows a distribution in two series (sub-periods) (Fig. 3). From 1983 to 2000, the temperature anomaly values are below the average temperature with a decreasing trend. On the other hand, there is an increasing trend above the mean value from 2001 to 2019. The trend line for annual temperature values overall shows a progression over time. The regression equation indicates that the temperature increases by 0.05 °C when moving from one year to the next (Fig. 2).

The student's t-test between the mean value of the period 1983–2000 (23.1 °C) and that of the period 2001–2019 (24.0 °C), shown in the anomaly diagram, shows a significant difference of almost 1 °C (p-value = 3.323e-08).

3.1.2. Precipitation changes from 1983 to 2019

Rainfall variations indicate an overall downward trend opposite to temperature, which varied from 1273 mm of rain in 1983 to 1150 mm in 2019. The fluctuations were weak over the 37 years of study (Figs. 4 and 5). The mean annual precipitation from 1983 to 2019 was 1290.85 ± 184.24 mm, used as a baseline for the analysis of the rainfall regime for the study period. The minimum annual average precipitation during this period was 787.33 mm, recorded in 1997. The maximum average yearly rainfall was 1687.28 mm, recorded in 2000, with a difference of 899.95 mm, corresponding to 60.99% of the average precipitation in 37 years. Hence, representing an average decrease of 15.25% per decade in this agro-ecological zone.

The anomaly curve (the deviation of annual precipitation from the yearly average value for the entire period) shows a highly variable trend (Fig. 4). However, years with positive anomalies have a higher frequency of occurrence (20 of 37 years studied). In contrast, the frequency of occurrence of deficit years becomes very rare, i.e., once every three years from 1998 onwards (17 of the 37 years). These observations derive two series (sub-series) 1983–1997 and 1998–2019.

The student's t-test harmonized with the test of temperature variation at the 0.05% threshold between the averages of the two sub-series (1983–2000 and 2001–2019), shows a decrease in precipitation of 95.36 mm, although it is not significant (p-value = 0.1317).

3.2. Local perceptions of climate change

3.2.1. Socio-demographic characteristics of the surveyed population

The characteristics of the respondents are presented in Table 1. The surveyed population is composed of an indigenous population (86%), 87% of whom depend on agricultural activities for their survival. The sample population is made up of 67% men and 33% women. The age of the majority of respondents (49%) vary between 25 and 44 years old. Only 2% of the respondents have higher education, and the majority of the surveyed population (64%) has a primary education.

3.2.2. Overall perception of climate change

In the context of climate change within the study population, 93% affirmed that they had noticed a real change in climate within their environment and subsequently confirmed a number of perceptions arising from Table 2.

More than 79% of households surveyed perceive a decrease in rainfall over the years. In addition, 84% reported a late start to the rains. Conversely, to these observations, more than 84% of respondents disagree that the rainy season lasts longer than before.

Concerning perceptions of the dry season, nearly 90% of households agree that it is warmer in the dry season and over 81% agree

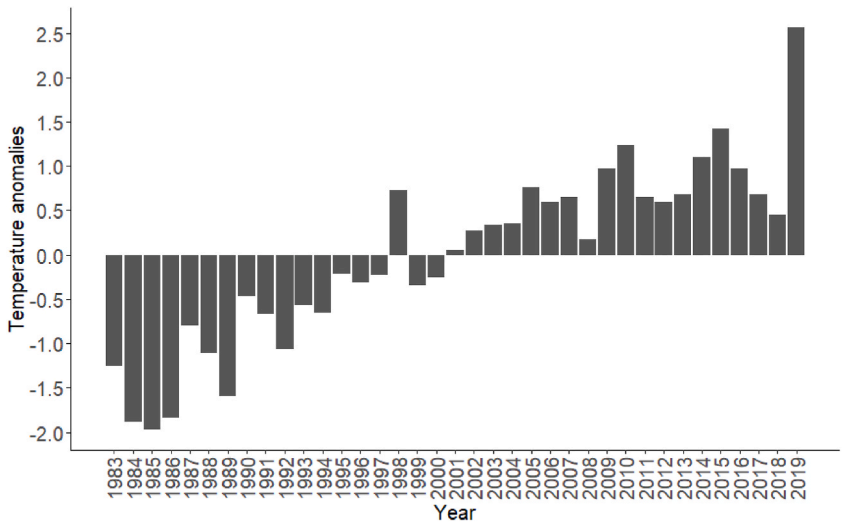

Fig. 3. Temperature anomaly evolution diagram for the period 1983–2019.

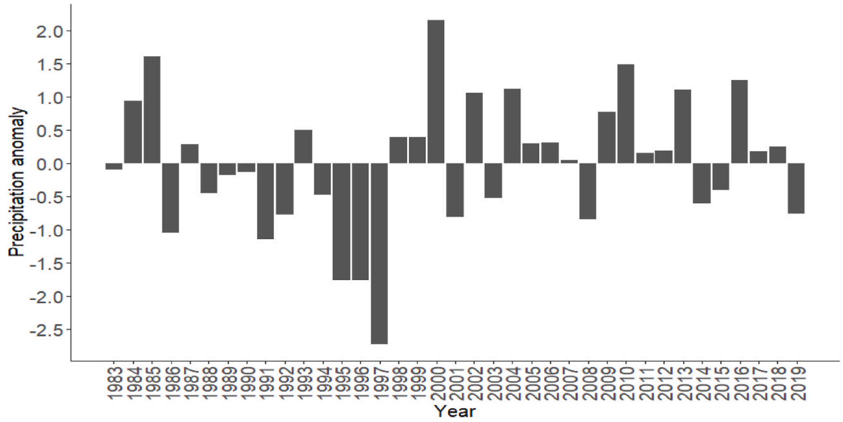

Fig. 4. Precipitation anomaly evolution diagram for the period 1983–2019.

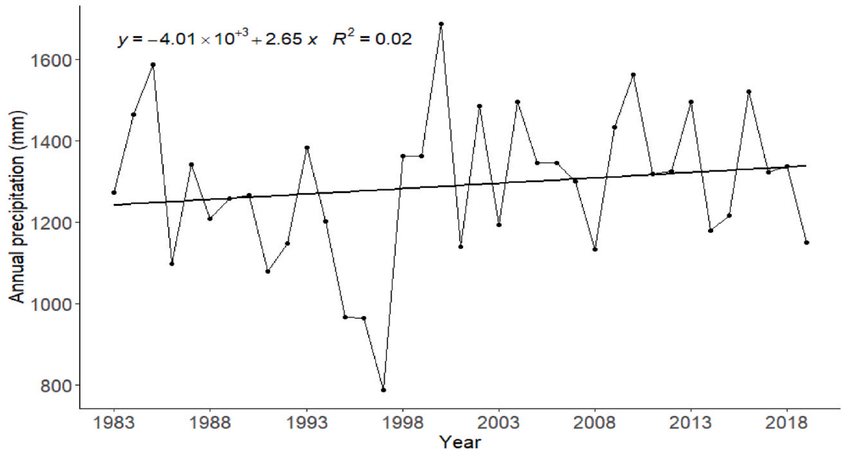

Fig. 5. Trend line of the evolution of Annual precipitation from 1983 to 2019.

Table 1
Socio-demographic characteristics of the surveyed population.

		Sample
		n = 540 (%)
Gender		
	Male	67
	Female	33
Age		
	20–24 years	15
	25–44 years	49
	≥45 years	36
Level of education		
	Never been to school	6
	Primary	64
	Secondary	28
	University level	2
Main occupation	Farming	87
	Forestry activity	10
	Fishing	1
	Other activities	2
Settlement duration	Autochthone	86
	More than 15 years	14

that dry spells are becoming recurrent in the zone with an increase in the length of the dry season (79% of households agree).

On the other hand, the increase in the frequency of rising waters is a parameter that has changed slightly, with 47% of households agreeing versus 53% disagreeing with an increase in the duration of rising waters in parallel. However, the recurrence of high winds is increasingly noted in the area, with 62% of households agreeing versus 38% disagreeing.

3.2.3. *Factors determining the perception of climate change*

The results of the multivariate logistic regression (Table 3) conducted to model the relationship between local perceptions and the socio-cultural characteristics (age, sex, education, occupation and duration of settlement) of the respondents show that the variables age, education and duration of settlement do not significantly influence on the climate change perception ($P > 0.05$). On the other hand, the late onset of rains, the regression of rains during the year, the increase in the duration of the dry season, the recurrence of drought and the recurrence of violent winds are perceptions significantly ($p < 0.05$) influenced by the main occupation of the respondents. This clarifies the link between activities directly dependent on climatic variations (agriculture, NTFP harvesting, animal husbandry …) and the perception of climate change.

Gender was also a strong factor influencing the perception of the recurrence of high winds with a p-value = 0.001, implying that men perceived it better than women.

3.2.4. *Impacts of climate change on local activities*

When asked about the adverse effects of climate change on their main activity (Fig. 6), the results of the respondents show that 52% of the farmers noted a decrease in yield and 38% show about proliferation of crops diseases. On the other hand, the drying up of rivers (6%) and the appearance of invasive species (4%) were observed at low rates. The major phenomena perceived by the people practicing forestry activities can be summarized as a decrease in non-timber forest products (36%), the disappearance of certain plant species (23%), an increase in animal diseases (12%), the disappearance of certain animals (18%), and the appearance of new plant species (8%) and animal species (3%). Fishing being the third main activity among the surveyed population, the negative effects attributed to climate change were seen such as a decrease in fishing yields (52%), rise in river levels (23%), drying up of rivers (15%) and disappearance of certain fish species (10%).

For those who do not practice an activity directly related to climate change, the major impacts are drying up of rivers (56%), increased disease in some domestic animals (24%), and decreased non-timber forest products (20%).

3.2.5. *Strategies of adaptation to climate change*

The alluvial diagram for adaptation to climate change presents measures by sector of activity in the municipality of Belabo (Fig. 7). By resume by this diagram, in agriculture, adaptation measures such as changing the cropping calendar (86%), moving to lowlands (6%), abandoning crops (4%), maintaining fallow (3%), and irrigation (1%) are noted. In the forestry sector, measures such as changing the timing of NTFP harvesting (75%), diversification of income (20%) and abandonment of activity (5%). In the fishing sector, people developed measures such as abandoning the activity (81%), changing the activity (11%) and changing the timing of the activity, i.e., shifting the fishing seasons (8%). For those practicing other activities, changing the cultural calendar was the only strategy (100%).

4. Discussion

4.1. *Climate variations from 1983 to 2019*

In general, the evolution of annual average temperatures in Eastern Cameroon shows evident warming since the 2001s. According to investigations conducted in Africa, the annual average temperature has increased during the last decades [23]. With the cause of greenhouse gas emissions resulting from anthropogenic activities, this increase is expected to continue at the end of the century according to the RCP4.5 scenario (2071–2100). The study of temperature anomaly variation shows two sub-periods with a statistically significant difference in mean temperature (1.1 °C) from 1983 to 2000 for the wet period to 2001–2019 for the dry period. This change in trend during the two sub-periods could be justified by the dynamics of intensified deforestation in the area. Indeed, current

Table 2
Summary of overall perceptions.

Observed parameters *n* = *540*	Yes	No
Less rainfall during the year	80	20
Late start of rainfall	84	16
Temperature changes in the rainy season	76	24
Increase in the length of the rainy season	7	93
More heat in the dry season	90	10
Recurrence of drought	82	18
Increase in the duration of the drought	80	21
Increased frequency of rising water	47	53
Increase in the duration of rising water	38	62
Recurrence of wild winds	62	38

Table 3
Relationships between explanatory variables and climate perceptions revealed by logical regression analysis. A = More heat in the dry season; B= Increased duration of the rainy season; C= Late onset of rains; D = Less rainfall during the year; E = Increased duration of the dry season; F= Recurrence of drought; G = Increased frequency of rising water; H= Increased duration of rising water; I= Recurrence of wild winds.

	Age			Gender			Education			Occupation			Settlement duration		
	Coef.	St. Error	*P*-Value	Coef.	St. Error	*P*-Value	Coef.	St. Error	*P*-Value	Coef.	St. Error	*P*-Value	Coef.	St. Error.	*P*-Value
A	−0.435	0.362	0.22	0.302	0.311	0.33	0.459	0.303	0.13	0.356	0.441	0.42	0.105	0.567	0.85
B	0.043	0.380	0.91	−0.029	0.373	0.94	0.139	0.381	0.71	0.196	0.508	0.70	−0.959	1.037	0.35
C	−0.068	0.271	0.80	0.302	0.257	0.24	0.279	0.255	0.27	0.838	0.327	**0.01****	0.227	0.452	0.62
D	−0.099	0.246	0.71	0.098	0.237	0.68	0.128	0.235	0.59	0.714	0.306	**0.01****	−0.012	0.447	0.98
E	−0.154	0.261	0.56	0.160	0.249	0.52	0.292	0.244	0.23	1.095	0.305	**0.00*****	0.104	0.453	0.82
F	−0.154	0.262	0.55	0.160	0.249	0.52	0.292	0.244	0.23	1.095	0.304	**0.00*****	0.104	0.453	0.23
G	0.167	0.196	0.40	−2.670	0.192	0.16	−0.315	0.192	0.10	−0.307	0.280	0.27	0.102	0.364	0.78
H	−0.007	0.202	0.97	0.364	0.199	0.06	0.341	0.200	0.09	0.212	0.288	0.46	−0.413	0.367	0.26
I	−0.144	0.204	0.48	0.612	0.198	**0.00****	−0.069	0.198	0.73	0.642	0.280	**0.02***	0.076	0.367	0.84

*Note*Signif. codes: 0 ‘***’0.001 ‘**’0.01 ‘*’0.05 ‘.’ 0.1 ‘ ’1.

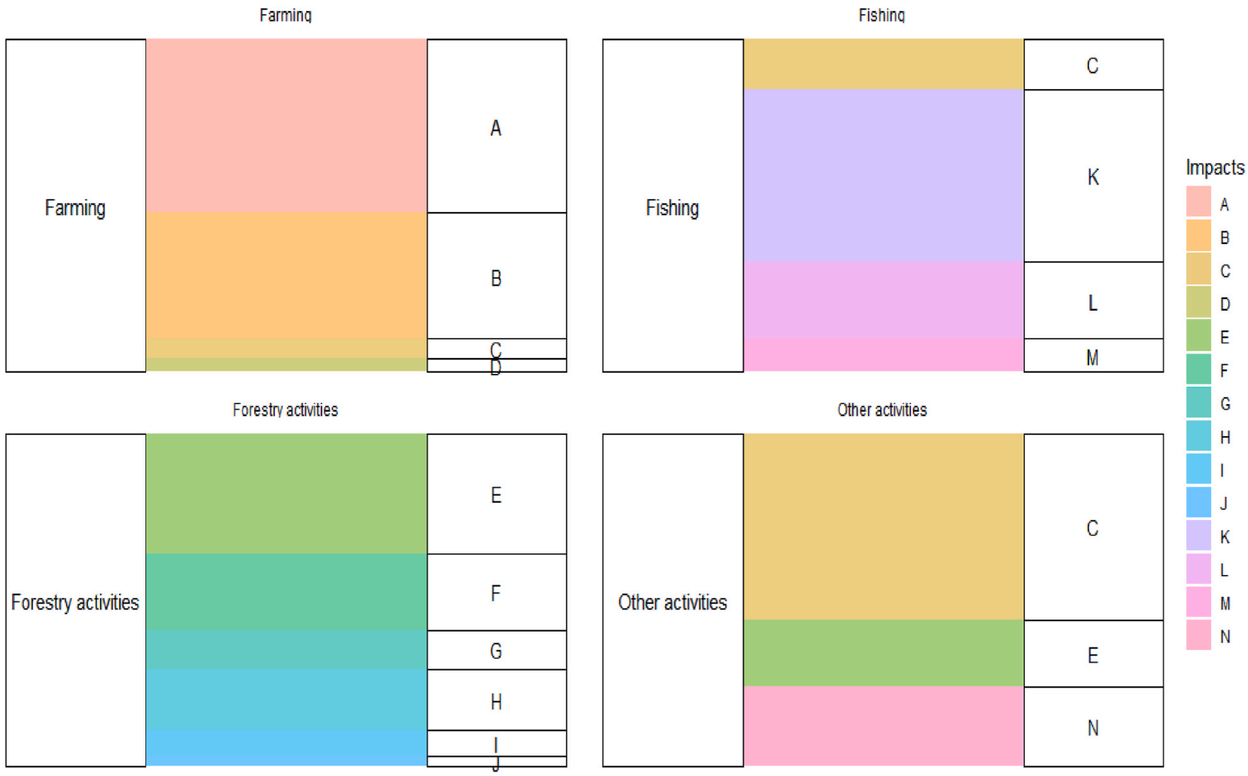

Fig. 6. Alluvial forests of the perceptions of the effects of climate change on activities. A = Decrease in yield; B = Proliferation of diseases on crops; C = Drying up of rivers; D = appearance of invasive species; E = Decrease in NTFPs; F = disappearance of plant species; G = Resurgence of diseases in animals; H = Disappearance of certain animals; I = appearance of new plant species; J = appearance of new animal species; K = Decrease in fishing yield; L = Rise in river levels; M = disappearance of some fish species; N = Resurgence of diseases in some animals.

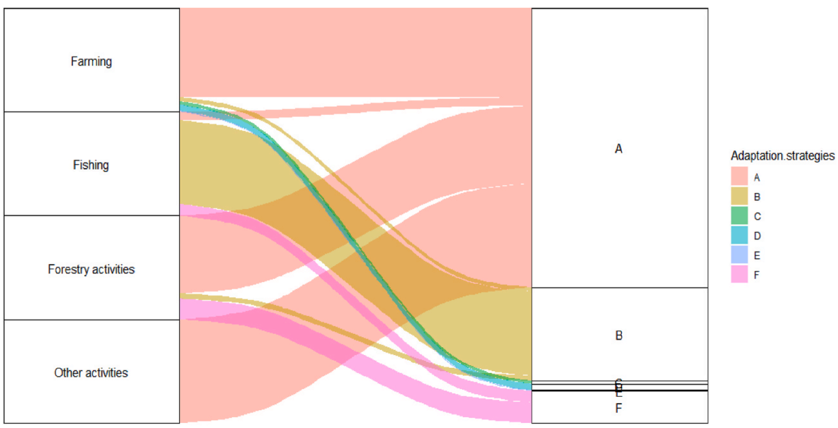

Fig. 7. Climate change adaptation strategies. A = Change in activity schedule; B = Abandon activity; C = Maintain fallow; D = Migration to lowlands; E = Irrigation; F = Income diversification.

deforestation rates in the Congo Basin show a progressive annual deforestation rate from 0.13% in 1990–2000 to 0.26% from 2000 to 2005 [46]. Multiple scenarios based on climate variations and land use types indicate that deforestation in the region could lead to warming between 2 and 4 °C due to decreased evapotranspiration (latent heat) and shading, combined with increased forcing resulting from lower greenhouse gas sequestration [47,48]. This upward trend was noted by MINEPDED [49] who estimated that the temperature increased by almost 1 °C during the 20th century in Cameroon who observed a temperature increase in the forest agro-ecological zone to which Belabo belongs of 1.84% per decade.

As for rainfall variations, they are very fluctuating and indicate an overall downward trend contrary to temperatures, with a peak in rainfall in 2001. The decrease in rainfall observed during the two sub-periods studied could also be justified by the phenomenon of accentuated deforestation highlighted by the populations. Indeed, for Lawrence and Vandecar [50], large forested areas are important in wind shear, air turbulence, and potential precipitation due to the thermodynamic engine engaged in transforming sensible heat to latent heat through vegetation leaves and leaf areas, and forest canopy. Thus, significant deforestation could lead to drier conditions and reduced precipitation [51]. Sighomnou [52] confirms that the period of 1971–2000 was deficient over the entire Cameroonian territory, previously noting this downward trend during 1983–2000. In addition, studies conducted by Ouemi et al. [53] confirm a deficit trend in Central and non-Sahelian West Africa from 1980 to 1990. The peak in rainfall in 2001 resulted from a significant decrease in annual rainfall amounts, which is noticeable by the contribution of the wet season, which progressively decreases at the expense of the dry season [54].

4.2. Local perceptions of climate change

The variations observed in climatic parameters, especially ambient temperature, and rainfall variations, are also perceptible at the level of the local populations, who can confirm with great certainty the observed trends and evaluate the consequences that result from them.

This study analyzed local perceptions of the effects of climate change, which is now a real threat. The results show that in the forest zone of Cameroon, local populations perceive the effects of climate change as well (92%) as the observations obtained after analysis of climate data. Indeed, the respondent people are more those who practice activities that are sensitive to climatic variations; these include agriculture, forestry activities, and fishing. Thus, the impact of climate change on their activities was easily perceptible by them. However, as far as the perception of flooding risks is concerned, it is practically absent in the Bélabo area, due to its geographical location (reported by a resident), which is confirmed by the literature. This also shows that the altitude in this area varies from 600 to 900 m. In fact, according to Din et al. [55], in Cameroon's coastal areas, where the altitude is almost zero, the risk of flooding related to climate change is reinforced by the increased frequency of extreme sea levels, waves and erosion. However, for the forest zone of Cameroon, climate variability related to increased temperatures during the dry season, shorter rainy season and increased variability of rainfall, late onset of the rainy season, and prolonged dry periods perceived by residents have been confirmed by several other authors in various zones in Cameroon [31,56,57].

Our results showed that unlike the other variables studied, gender and occupation were determinants of climate change perception. It can be said from these analyses that men are more objective in their perceptions than women. Men have a greater knowledge of climate change than women. This can be explained by the low level of education among women in the Bélabo zone [58]. The difference between an early and late season. This influence of gender on the perception of climatic variations is contrary to that obtained by Pauline Marcoty [59]. In the western part of Cameroon in a context where schooling is not strongly dependent on gender. Regarding the main occupation, it appears that the households with climate-dependent activities such as agriculture, fishing and NTFP collection are more likely to detect changes in the start of the season than changes in rainfall distribution and drought frequency [60]. In the case of agriculture, for example, the late start of the rains, the reduction in the amount of annual rainfall, the increase in the length of the dry season and the recurrence of drought are perceptions directly linked to their activity given the direct impact. These observations have been obtained by several authors [35,61–63].

The perception of climate change by populations remains complex, dynamic, and specific to each community and household. Although it remains a set of perceptions, people who have been through a long period and experienced droughts, floods, heatwaves, cold waves, etc., may be more aware and adopt sustainable behaviors and/or more appropriate adaptation practices [21].

4.3. Impacts of climate change perception on riparian activities

This study shows that the impacts of climate change perceived by the population based on agricultural activities, the decrease in yields could be related to the drying up of water courses that can be explained by the decrease in rainfall revealed at the level of the analyzed climatic data [63]. Water is an essential factor for the growth of plants because water constitutes more than 80% of the content of the cells and plays an essential role in most of the metabolic processes and the circulation of mineral elements [64]. Dimon [65] noted this decrease in yield during a study on adaptation to climate change in the municipalities of Kandi and Banikoara, in northern Benin. The study found that 88% of the farmers surveyed attributed the negative effects of rainfall fluctuations and temperature increases to the decline in yields.

The crop and animal diseases highlighted in specific sectors of activity as effects of climate change can be explained by the scarcity of improved seeds capable of withstanding the climatic variations observed and improved sources capable of withstanding the climatic variations observed. In fact, according to the IOM [66], local, regional, or global climatic variations will induce direct and indirect causes with predictable infectious effects on human, animal, and plant health. In addition, the study identified the perceived impacts on biodiversity. Indeed, the increase in temperature and the modification of precipitation regimes in the municipality of Belabo would be at the origin of the drought perceived by the populations that could create a decrease in defense of the trees leading them to mortality. Loehman et al. [67] assert that drought impacts lead to direct long-term consequences, and induced disturbances can lead to more immediate changes in the structure and function of forest ecosystems. Bélé et al. [68] state that all forest landscapes in Cameroon are affected by climate fluctuations, and changes confirm the vulnerability relayed in the municipality of Belabo to climate change. In addition, the MINEF [69] states in a study analyzing the impacts of climate change in Cameroon that all development sectors have mainly been impacted. The perception of effects in other activities independent of climate variations can be justified because all households in the town of Belabo practice agriculture, fishing, and NTFP harvesting for their subsistence needs.

4.4. Local climate change adaptation strategies

Faced with the agricultural sector's vulnerability to climate change, there is a lack of appropriate strategies in all sectors of activity in study area which could be explained by the low monthly income that households emphasize, which does not allow them to afford improved seeds or develop technologies that are more appropriate. More than 50% of the poor population lives in rural areas in Cameroon, with a high incidence in forest areas [70]. Masud et al. [36] found similar results; they showed that economic barriers significantly impact adaptive capacity and represent a key issue in adaptation measures. For In addition, limited knowledge of the effects of climate change would be a natural barrier to accessing adaptation [21,71,72]. Nevertheless, significant differences were also observed regarding the adaptation strategies used in these industries. Farmers reported using some techniques including altering the cropping calendar (86%), moving to lowlands (6%), abandoning cultivation (4%), maintaining fallow (3%), and irrigation (1%). In this case, the change in timing, the use of inland valleys, and irrigation would result from the intense periods of drought reported coupled with the different rainfall fluctuations noted. The maintenance of fallow land is a strategy for improving soil fertility, given the lack of means to obtain appropriate soil amendments [35]. These strategies are different from those identified by Ngute et al. [33], who report the implementation of more appropriate techniques such as drought-resistant crops and pesticides as adaptation responses among farmers and herders in the highlands of Cameroon. This diversification of strategies would be due to the support that the populations receive from civil society organizations established in this zone.

The forest resource is an essential asset for the subsistence of millions of Cameroonians and the country's development [73,74]. Despite its vulnerability to climate change, appropriate strategies such as reforestation of degraded or cleared areas, control and monitoring of timber exploitation, regulation of sand extraction, reduction of pollution from land use, and relocation of fishing camps behind mangroves have not been implemented [75]. In this sector of activity, modification of the activity calendar is adopted as local adaptation measures. The difficulties adaptation reported here could be justified by the low institutional and policy intervention level in the forestry sector. Indeed, a study commissioned by the United Nations Institute for Training and Research reveals that many African countries, including Cameroon, do not consider climate change as a priority in their decision-making processes and long-term forest management plans [76]. However, Zenghelis [77] argue that forests are an indispensable entry point for adaptation.

The fishing sector is also subject to a delay in implementing adaptation strategies in the face of the impacts perceived by the populations. Indeed, the high rate of respondents who have abandoned the activity (81%) or changed their activity (11%) as opposed to (8%) who have complied with the new fluctuating fishing calendar. This could be explained by the fact that the fishing technique in the municipality is mostly manual and based on the drastic drying up of the rivers in periods of drought. However, with the phenomenon of continuously rising water reported by the respondents, it becomes almost impossible to carry out the activity at the expected time. The respondents conformed to the new agricultural calendar because agriculture, fishing, and others are considered heritage and subsistence activities in the municipality since they are involved in other sectors of activity such as trade and motorcycle driving.

5. Conclusion

This study links climate change and local perceptions and highlights the need to strengthen climate change adaptation strategies in Cameroon. Indeed, information on local knowledge and perceptions of climate change and households adaptation strategies in developing countries is scarce. Therefore, the present study has made it possible to describe the evolution of specific climatic parameters (temperature and rainfall) from 1983 to 2019 and the resulting local perceptions. It shows a significant increase in temperature and an insignificant decrease in annual precipitation. Furthermore, the described climatic variations corroborate with the local perceptions on climate change and gender and main occupation were identified like the principal factor that can explain these local perceptions. In addition, the results allowed us to highlight the absence of adaptation measures despite the different impacts declared by the respondents in various sectors of activity, once again underlining the need to improve climate change adaptation strategies in Africa. Due to the fact that in many African countries like Cameroon, climate change and adaptability measures are not considered a priority in their decision-making processes and long-term forest management plans due to lack of available information. Hence, a census of the perceptions of the population of the Belabo area and the different approaches by sector of activity would allow a decision to be taken by policy-makers on implementing more appropriate strategies that respond to the current realities and then help local people to face to this warming phenomena.

Author contribution statement

Guylène Ngoukwa, PhD student; Cédric Chimi Djomo, PhD: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Libalah Moses Bakonck, Lecturer: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Louis-Paul Roger Kabelong Banoho, Lecturer; Jules Christian Zekeng, PhD; Louis Zapfack, Professor: Conceived and designed the experiments; Performed the experiments; Wrote the paper.

Amandine Ntonmen Yonkeu, PhD; Roger Bruno Tabue Mbobda, PhD; Armel Lekeufack, PhD student; Bienvenu Leonnel Tchonang Djoumbi, Master; Jean Jules Nana Ndangang, PhD Student; Hubert Mounmemi Mpoumie, PhD; Melanie Bawou A Rim, Master; Atabong Paul Agendia, PhD student; Ingrid Temfack Tsopmejio, PhD student; Vidal Djoukang Nguimfack, Master; Pierre Nbendah, PhD student; Narcisse Emile Njila Nana, PhD student: Contributed reagents, materials, analysis tools or data.

Data availability statement

Data included in article/supp. material/referenced in article.

Additional information

Supplementary content related to this article has been published online at [URL].

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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